The sPHENIX Experiment

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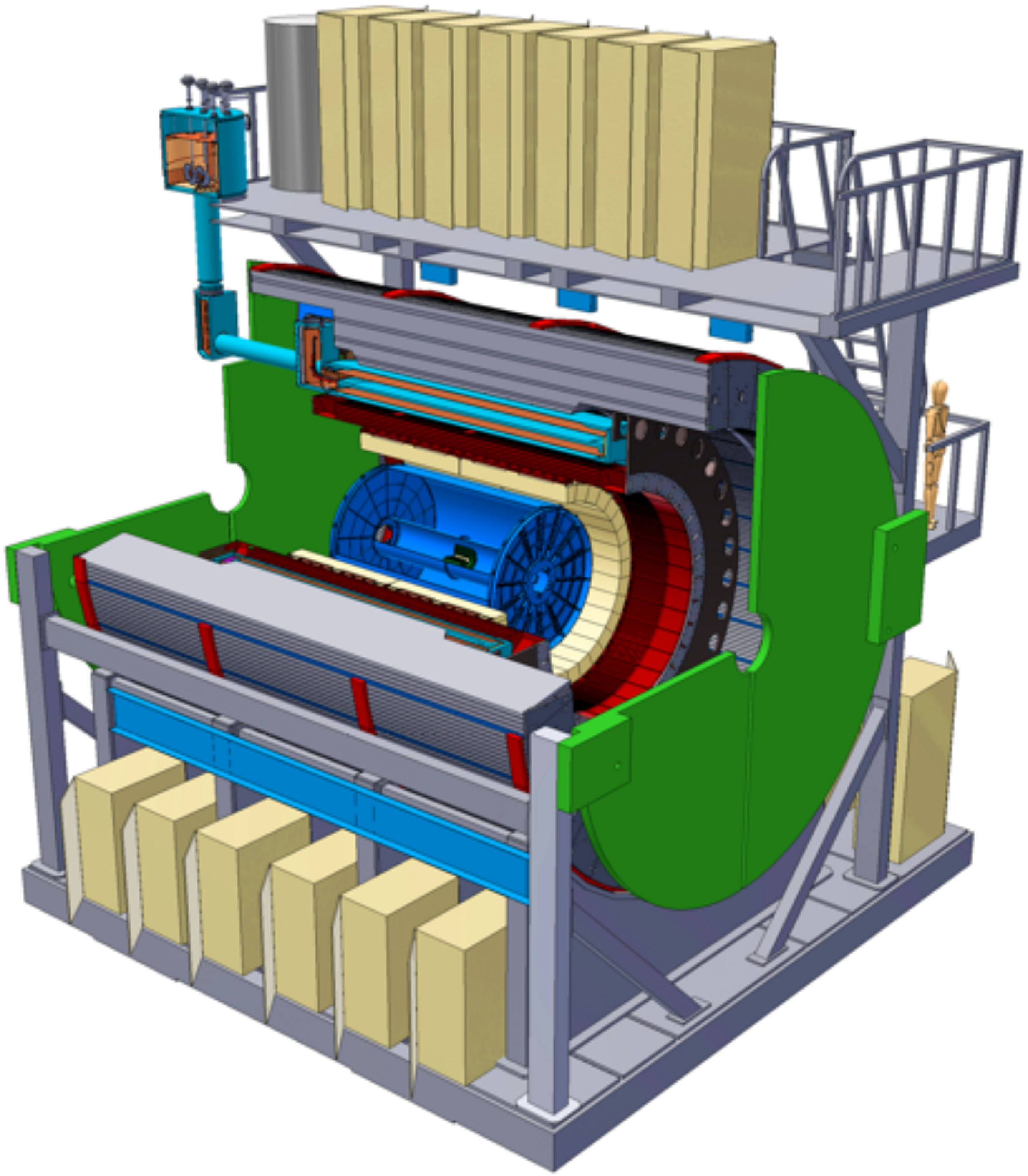
For the sPHENIX Collaboration

RHIC/AGS User's Meeting
June 12-15, 2018

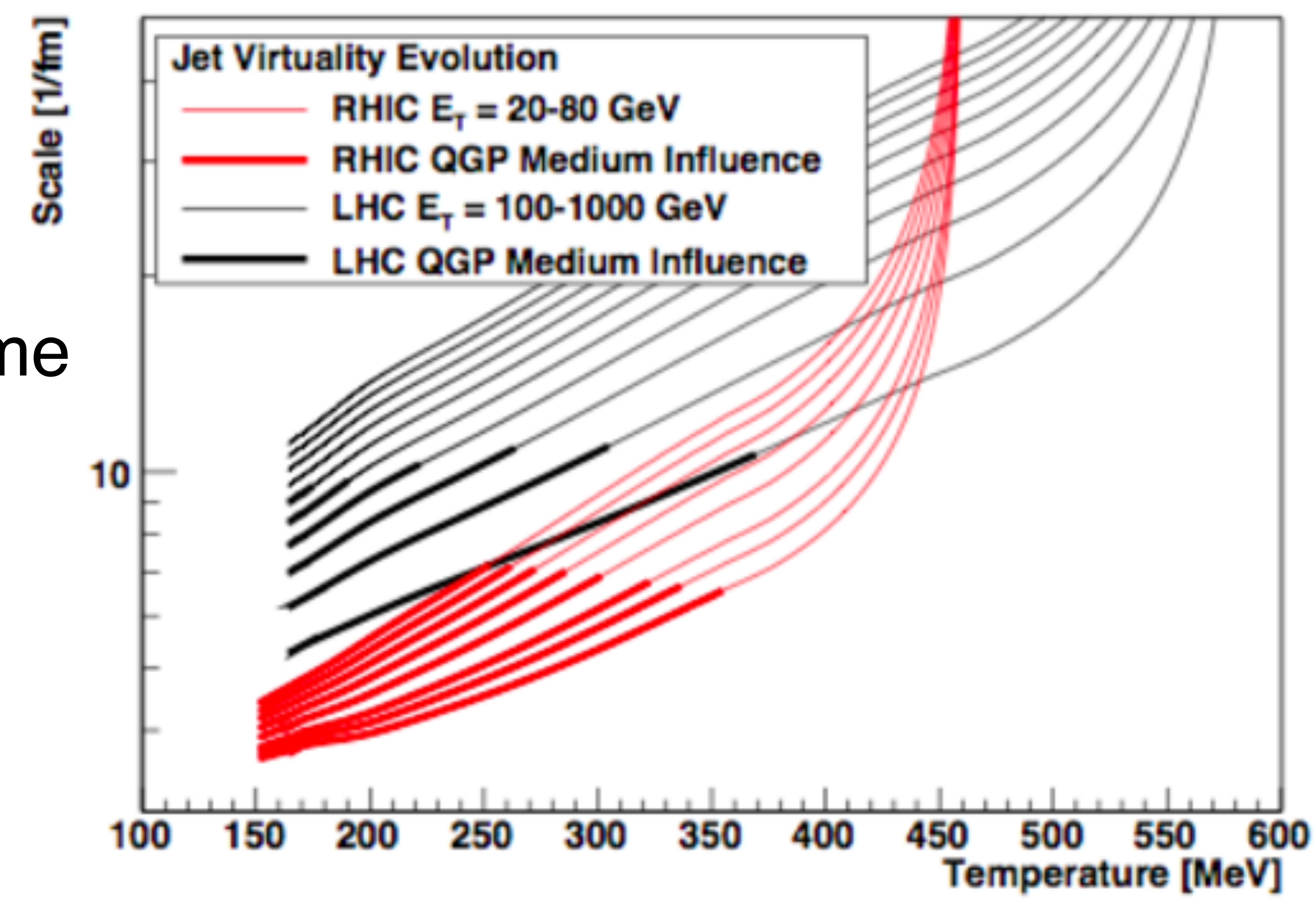


RHIC and LHC Measurements are Complementary

Initial conditions and QGP evolution at RHIC and LHC are different!

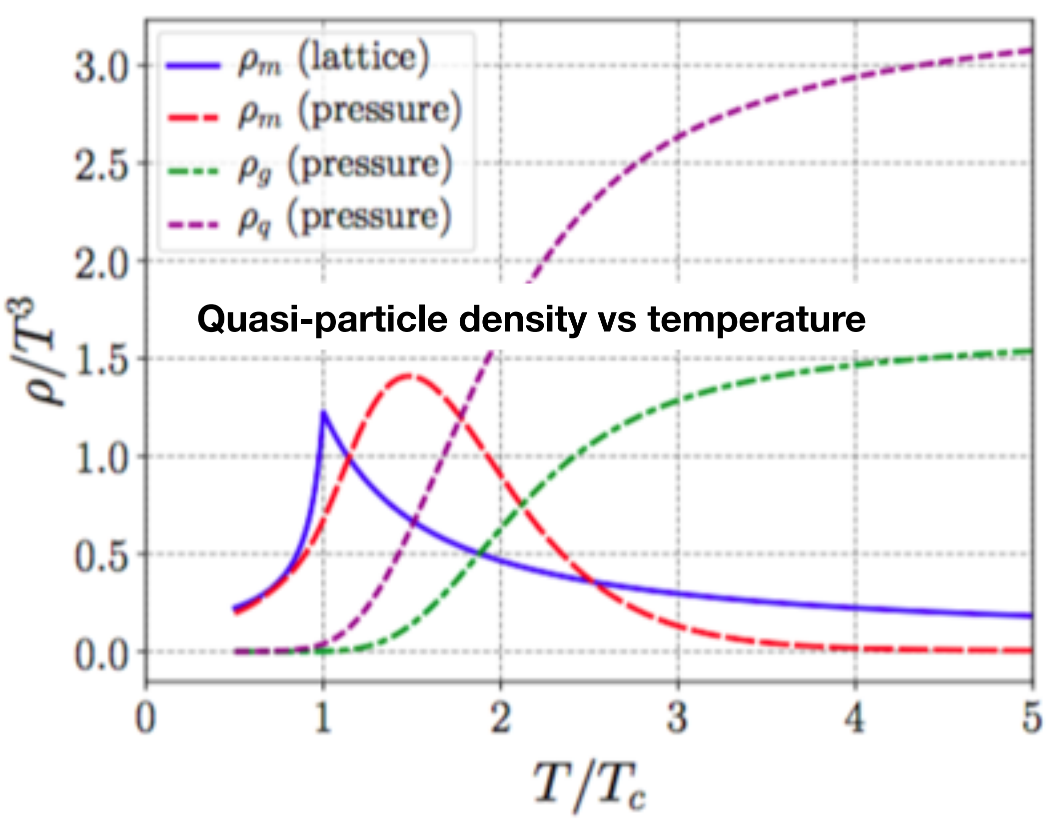
- Use combined data to extract T dependence

M. Habich, J. Nagle, and P. Romatschke, EPJC, 75:15 (2015)



The QGP spends more time near T_c at RHIC energy

A. Ramamurti, E. Shuryak, Phys. Rev. D 97, 016010 (2018)

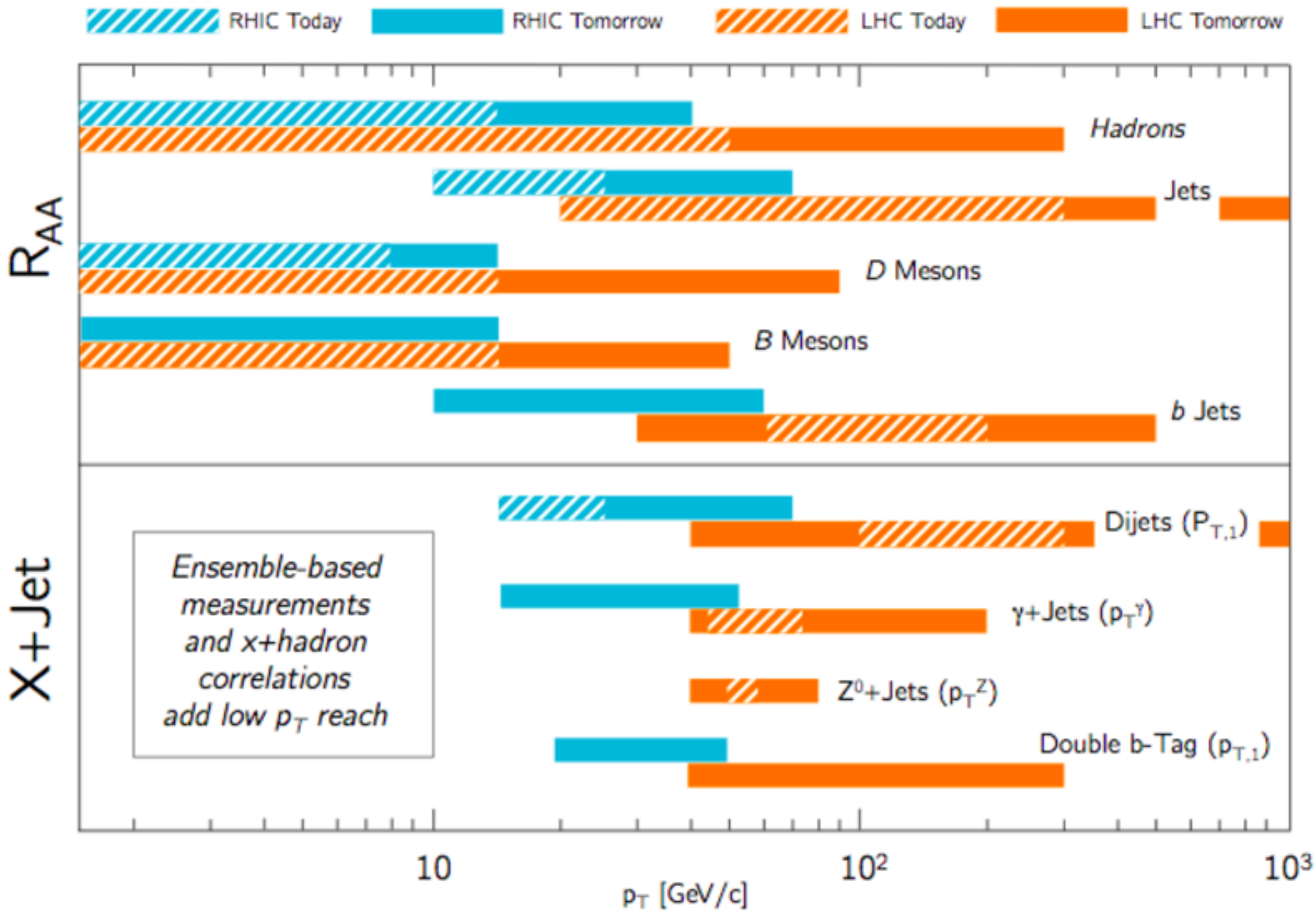


The structure of the QGP is expected to depend on temperature

Complementary Kinematic Reach

Low pT at RHIC

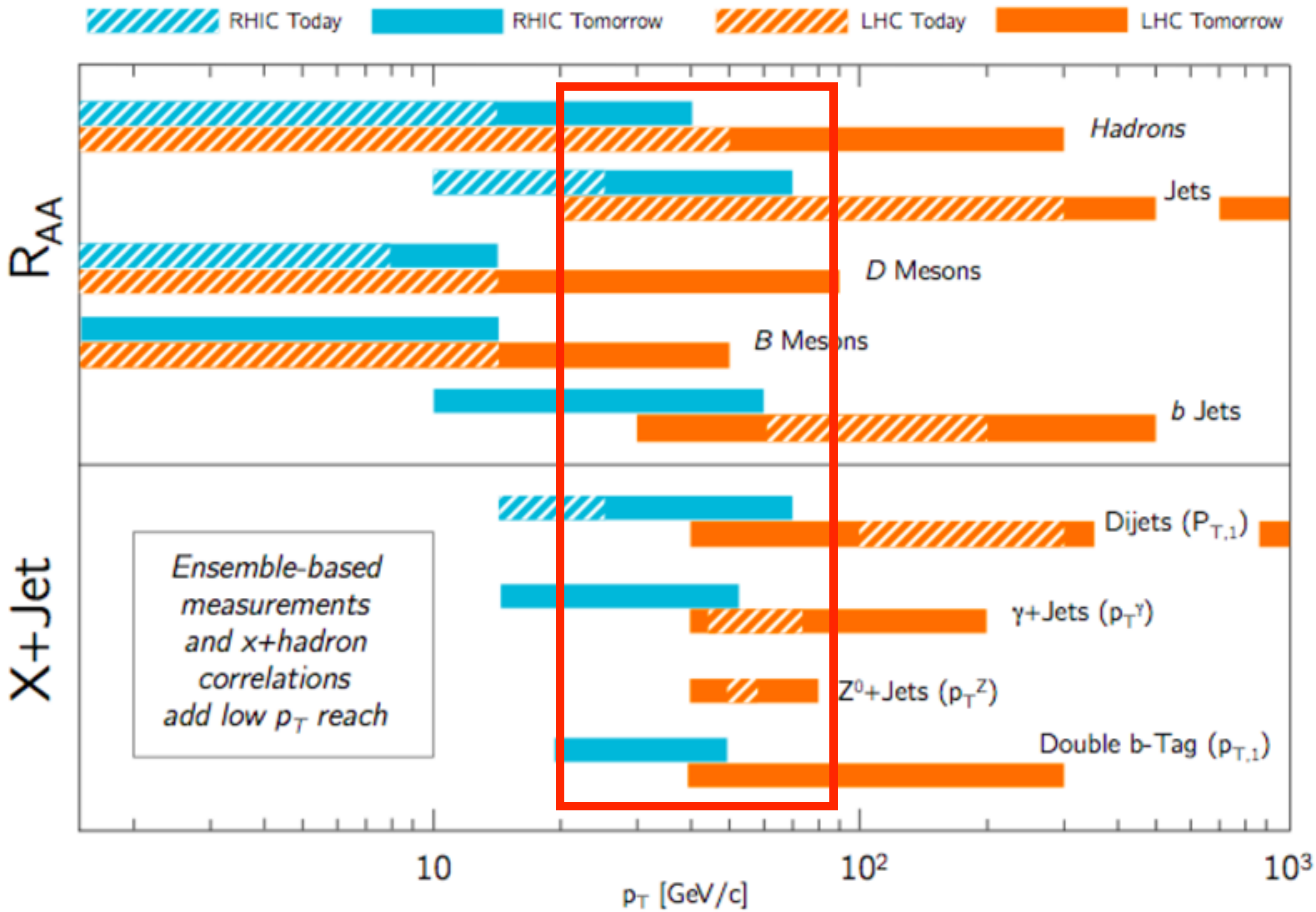
High pT at LHC



Overlaps → same probe, different QGP evolution

Low pT at RHIC

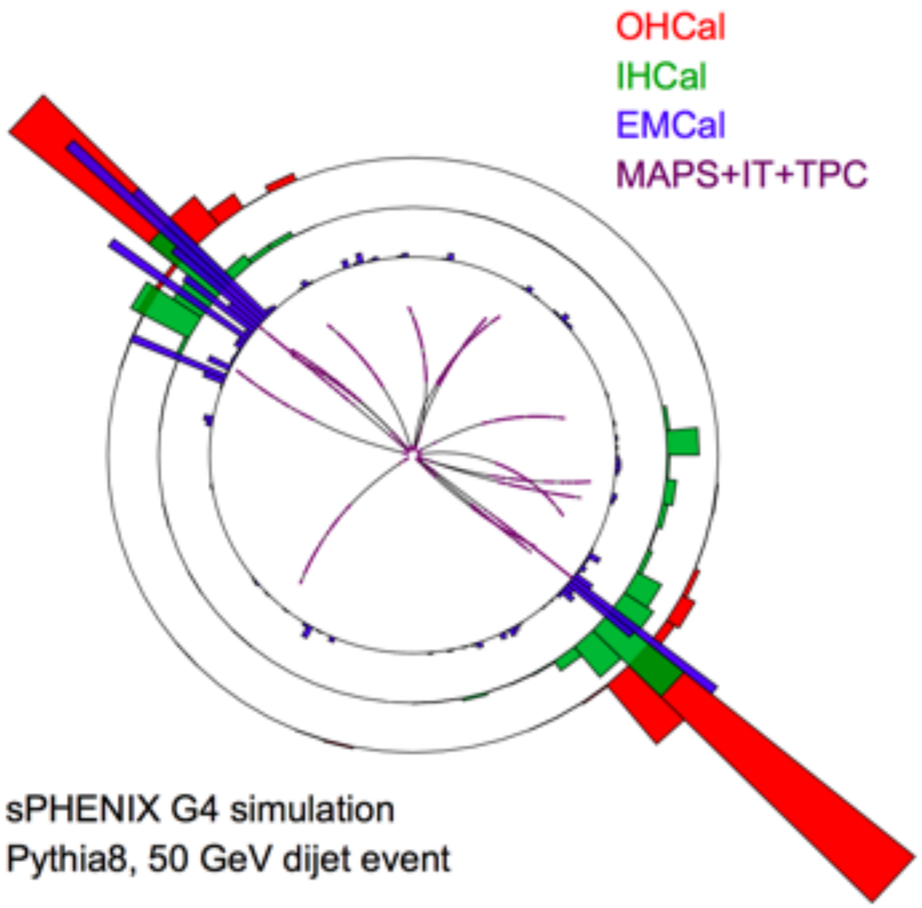
High pT at LHC

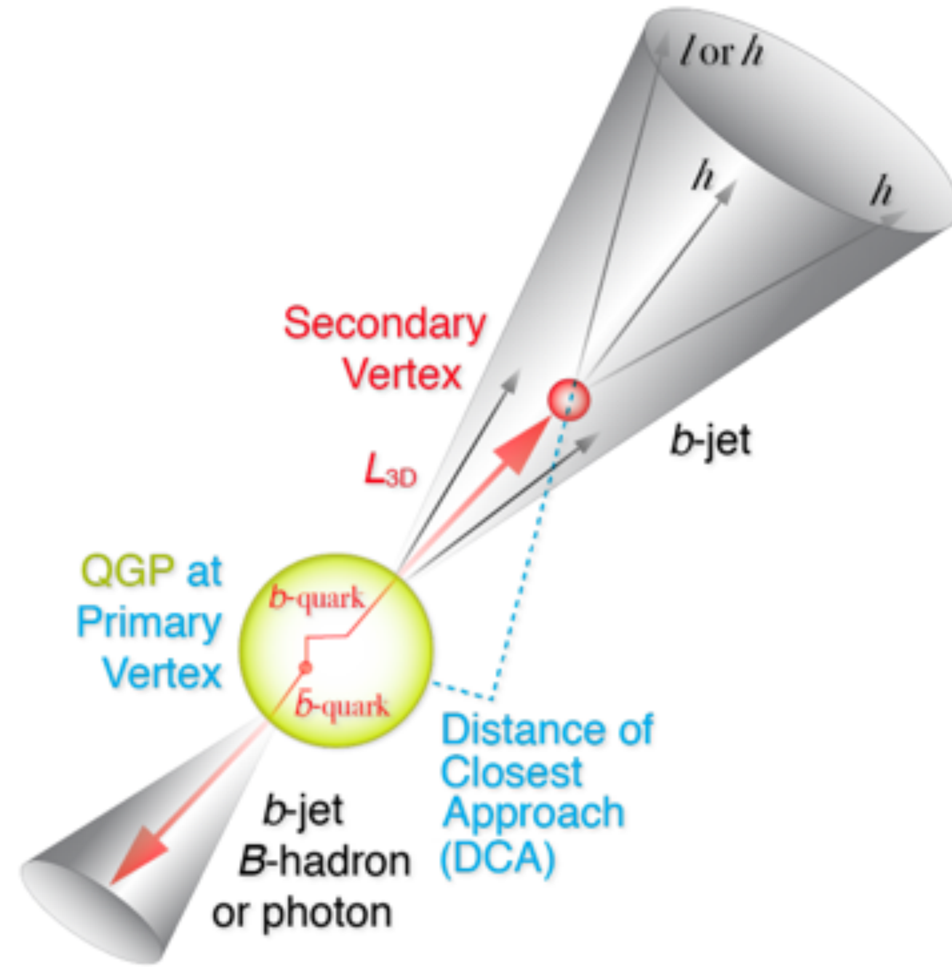


The sPHENIX Physics Program

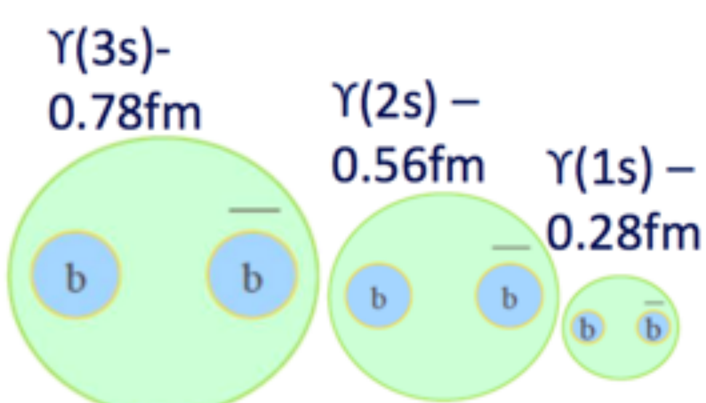
The sPHENIX physics program has three major legs

Jets



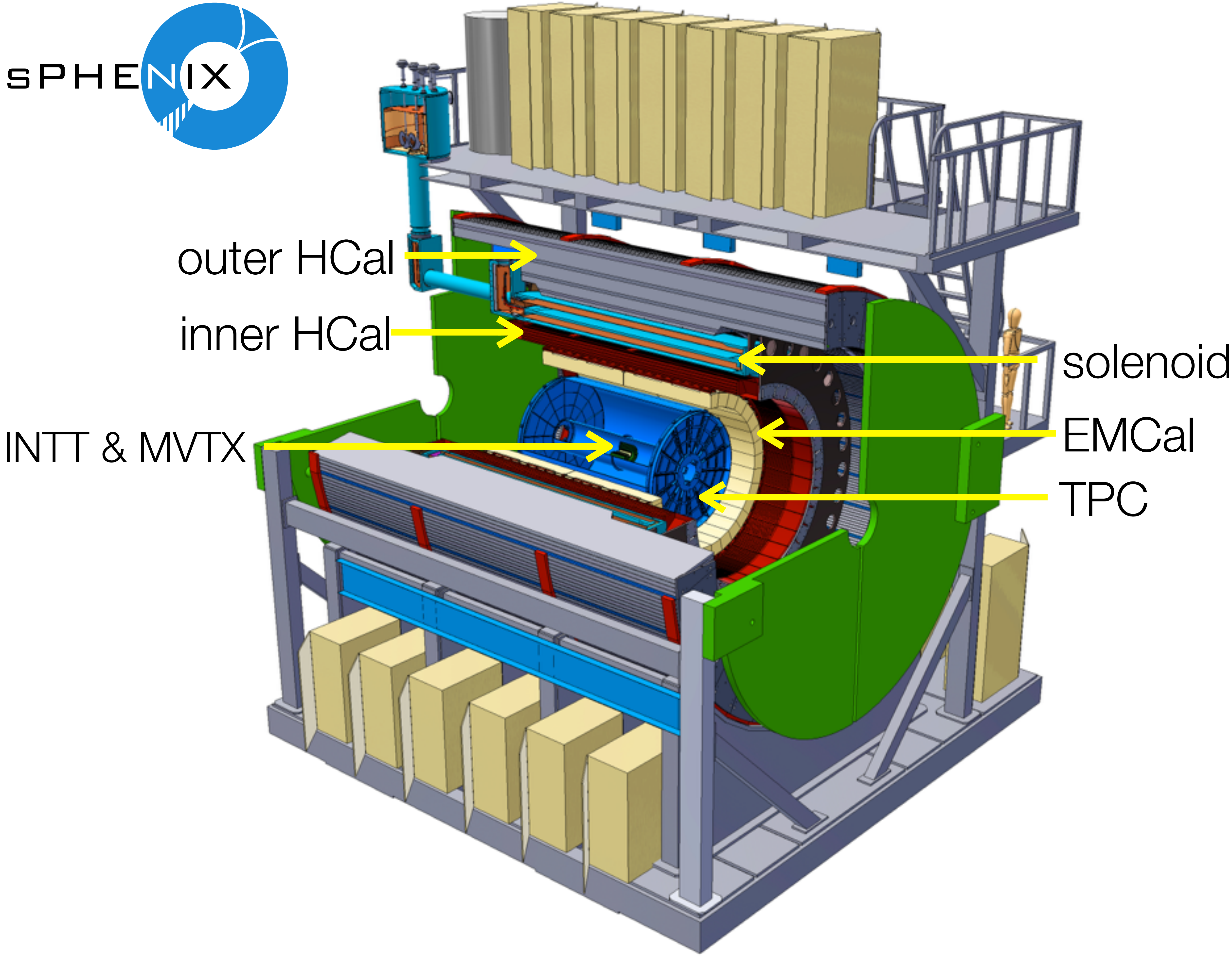


Upsilons

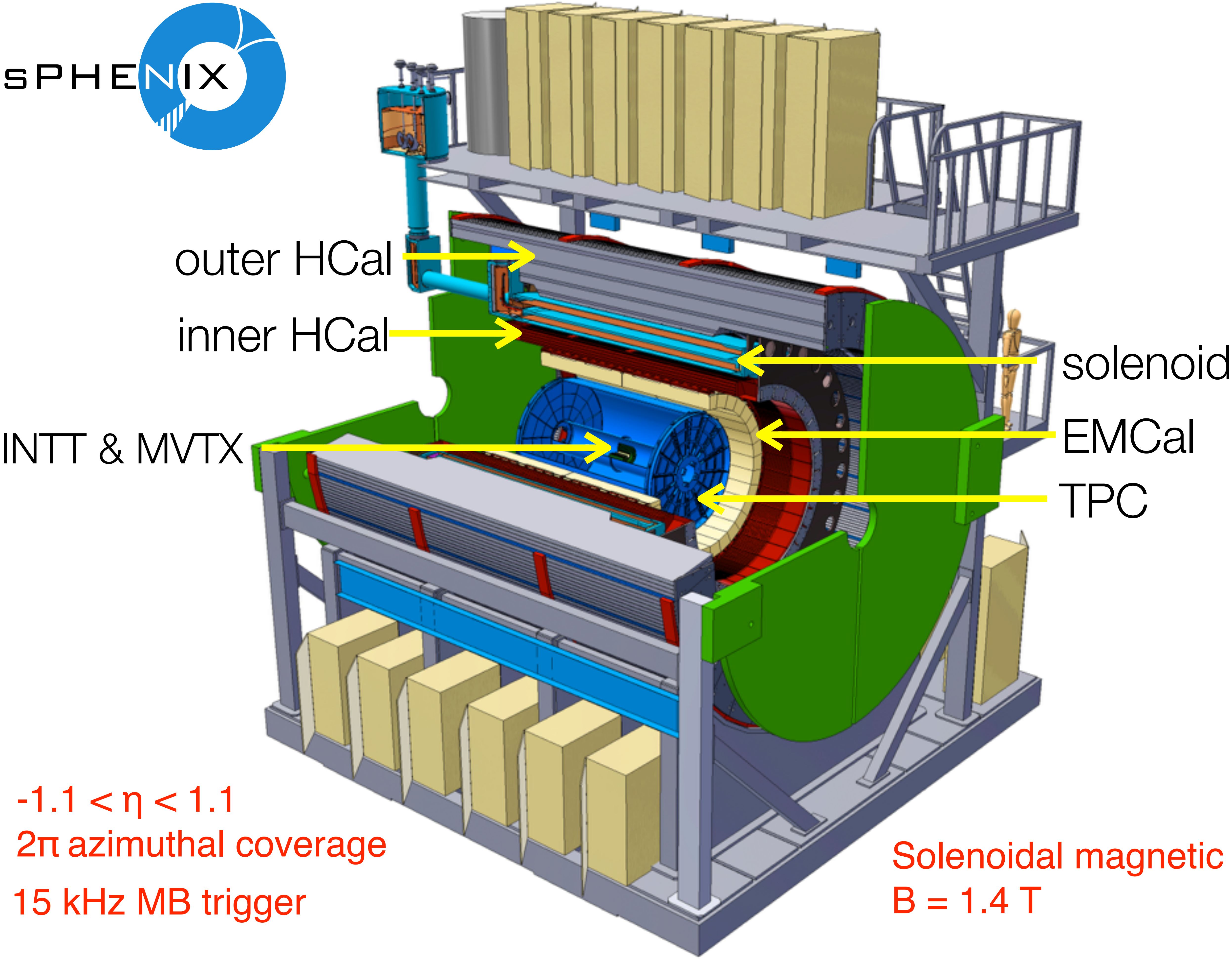


Heavy flavor

with the goal of studying these in p+p, p+Au and Au+Au collisions


outer HCal
inner HCal
solenoid
EMCal
INTT & MVTX
TPC

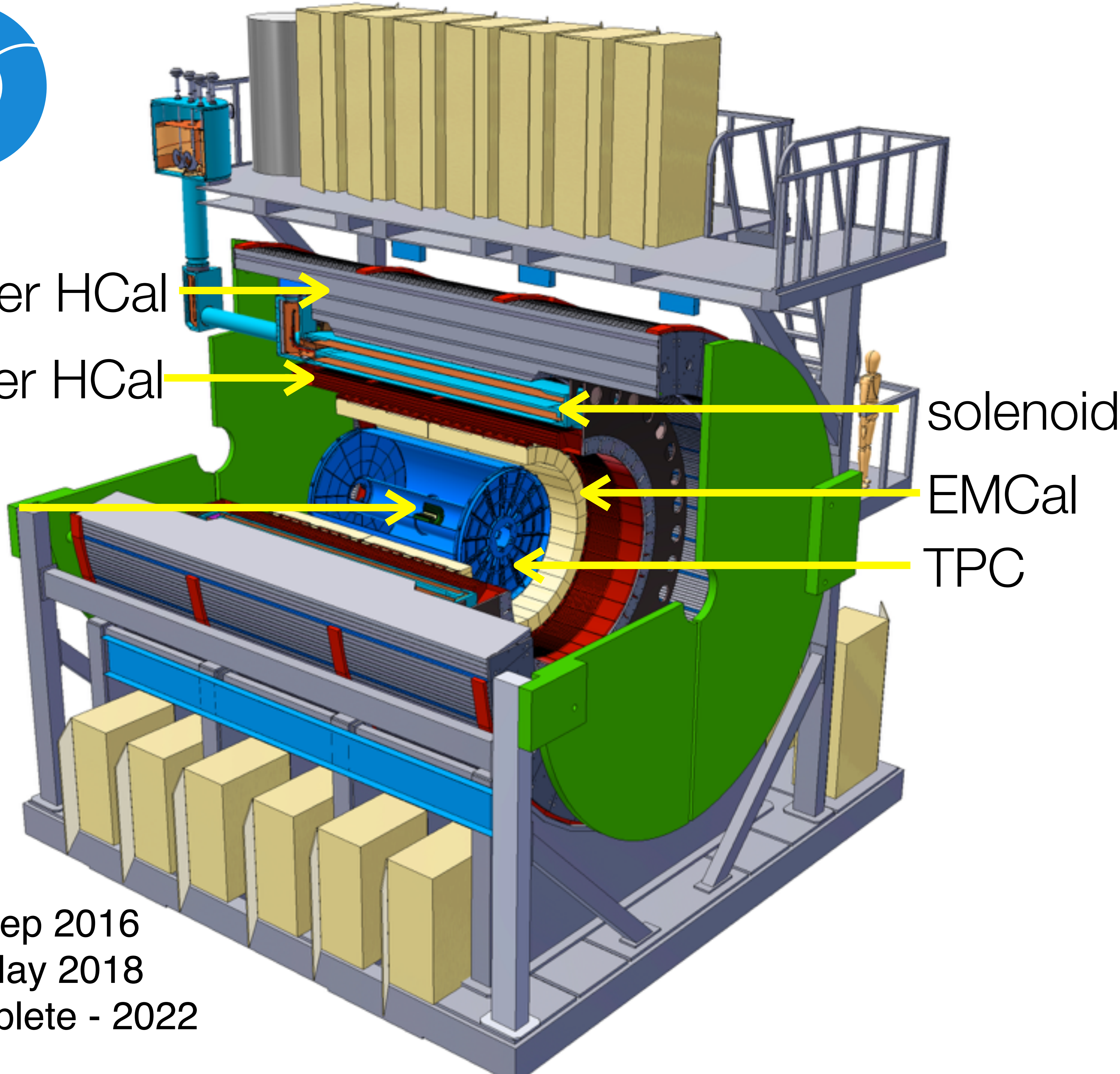
sPHENIX



$-1.1 < \eta < 1.1$
2π azimuthal coverage

15 kHz MB trigger

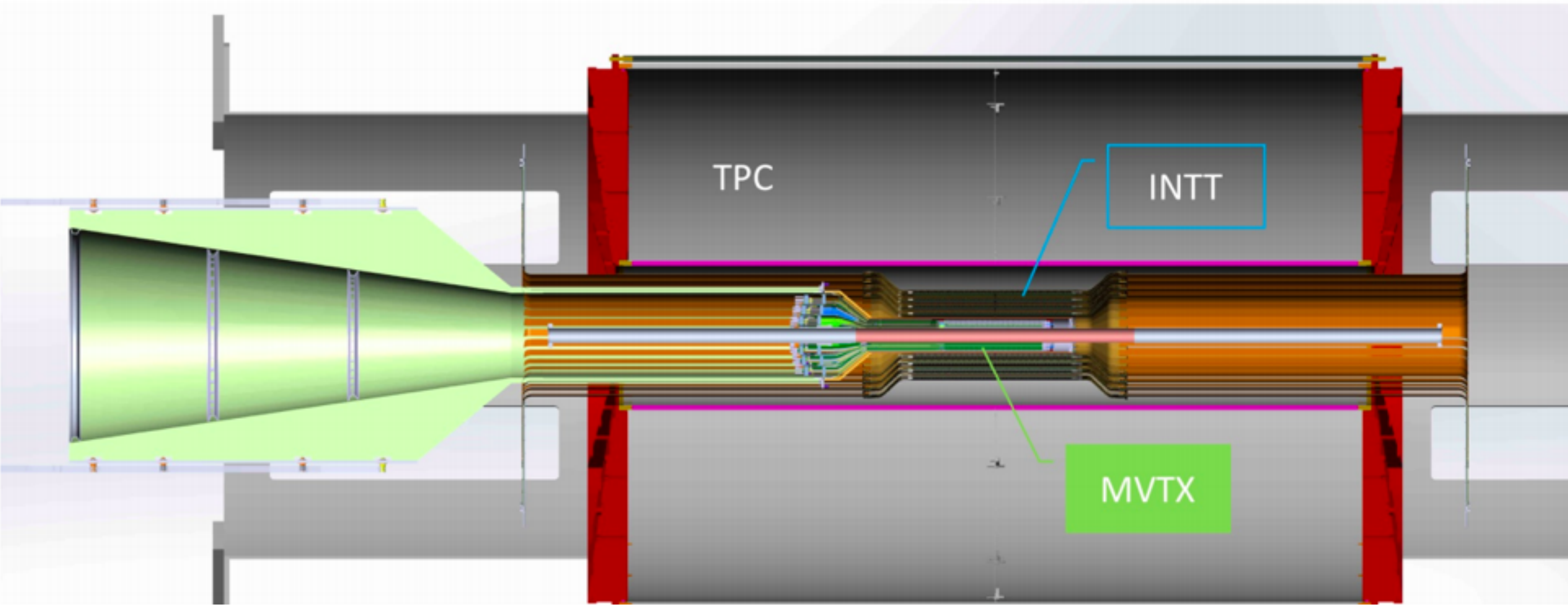
Solenoidal magnetic field
B = 1.4 T



Timeline

CD0 Review - Sep 2016
CD1 Review - May 2018
Installation complete - 2022
Running - 2023

The Tracking detectors

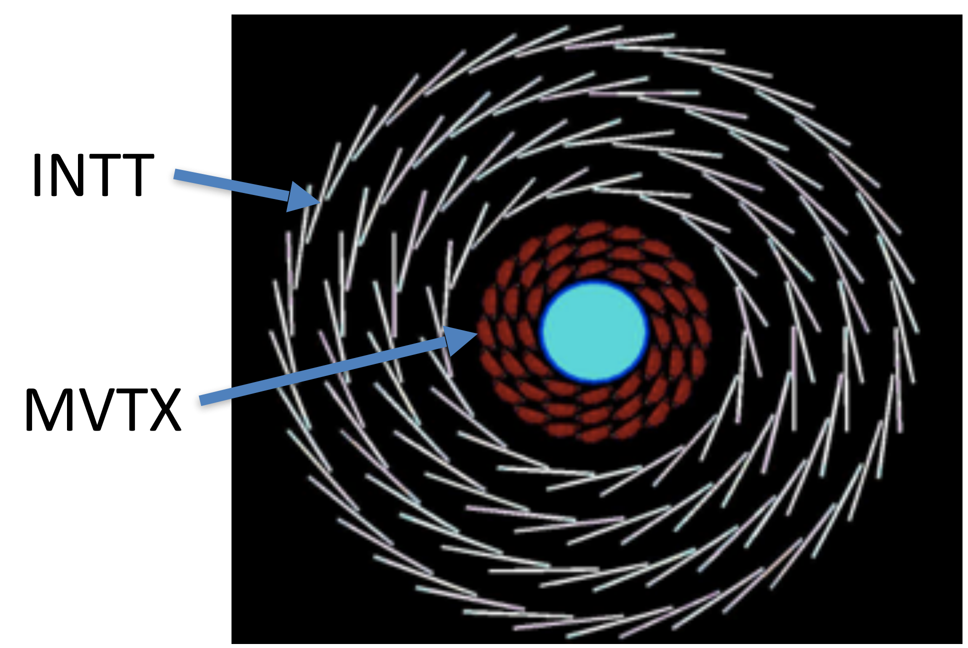


Functions:

TPC - momentum measurement

MVTX - precise track vertex

INTT - timing & pattern recognition



The Tracking detectors

TPC - Gateless, continuous readout

- 90:10 Ne-CF4 gas - low diffusion + high ion mobility
- Electron drift velocity 8 cm/µs - 13.2 µs maximum drift time
- Quad GEM electron multiplier + chevron readout pads
- 40 layer readout covering 30 - 78 cm radius
- R-ϕ resolution ~ 150 µm
- Δp/p ~ 1% at 5 GeV/c

INTT - Silicon strips with 80 µm pitch

- 4 layers 6 < R < 12 cm
- Pitch 78 µm
- Fast - can resolve one beam crossing

MVTX - 30 µm pitch MAPS pixels

- 3 layers 2.3 < R < 3.9 cm
- ~ 5 µm space point precision each

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Integration windows / events:

	Window	Au+Au	p+p
	μs	200 kHz	13 MHz
TPC	± 13.2	5	343
MVTX	± 5	2	130
INTT	-.02 +.08	1	1.3

This event “pileup” is properly included in all simulations

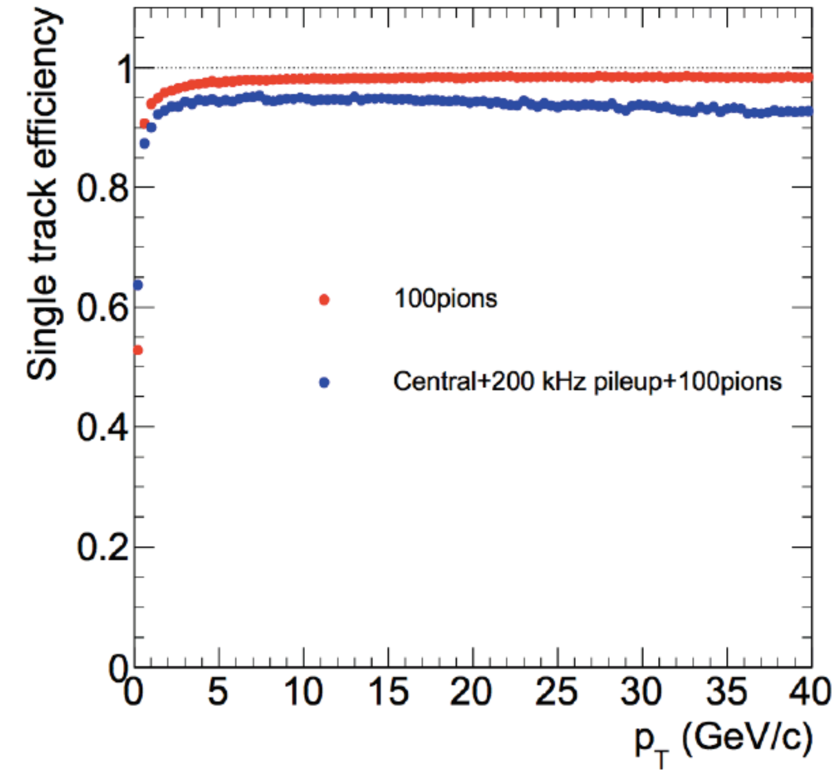
The INTT’s main function is to resolve ambiguities due to pileup

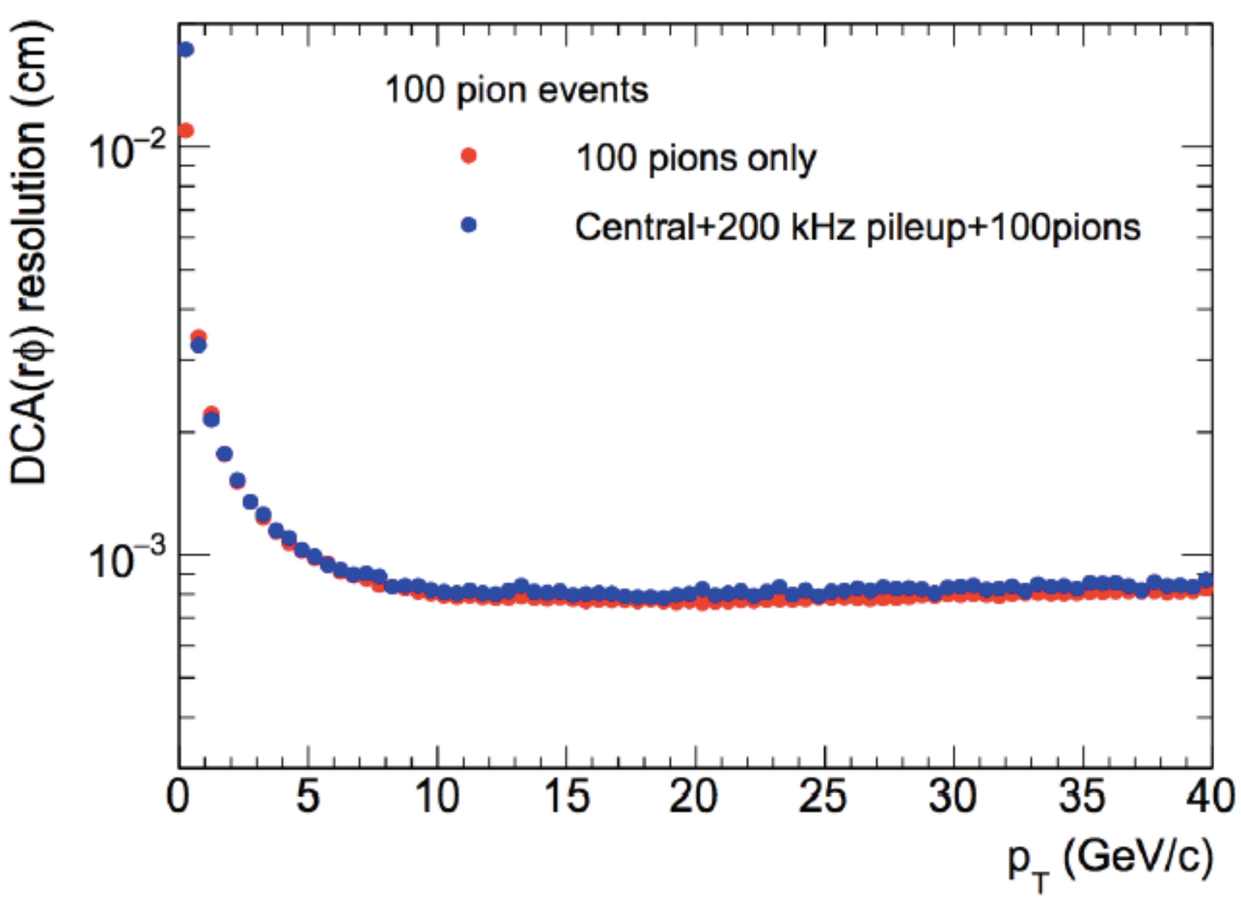
Tracking Performance

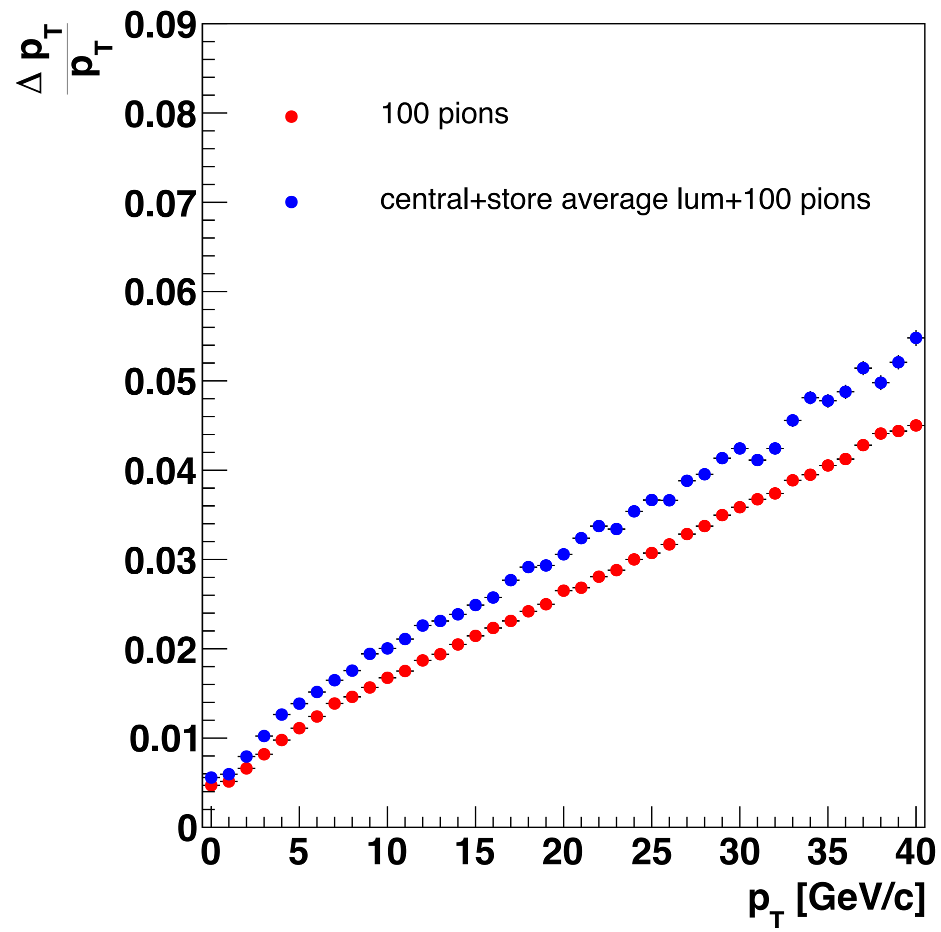
Simulated performance for

- Low occupancy events (100 pions)
- 0-4 fm Hijing Au+Au + 200 kHz event rate
  - (0-7% central, 100 pions embedded)

Have not yet implemented clustering designed to handle overlaps







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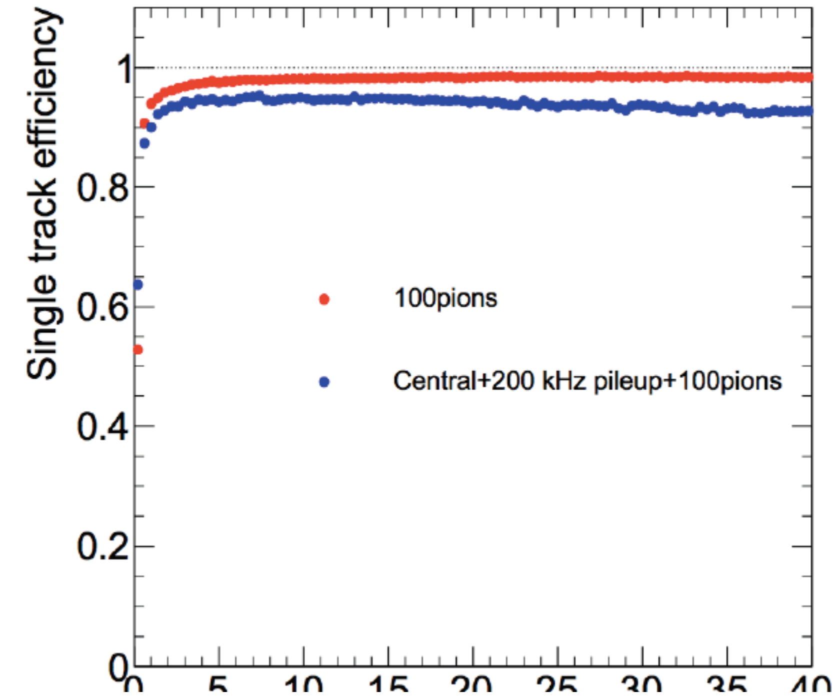
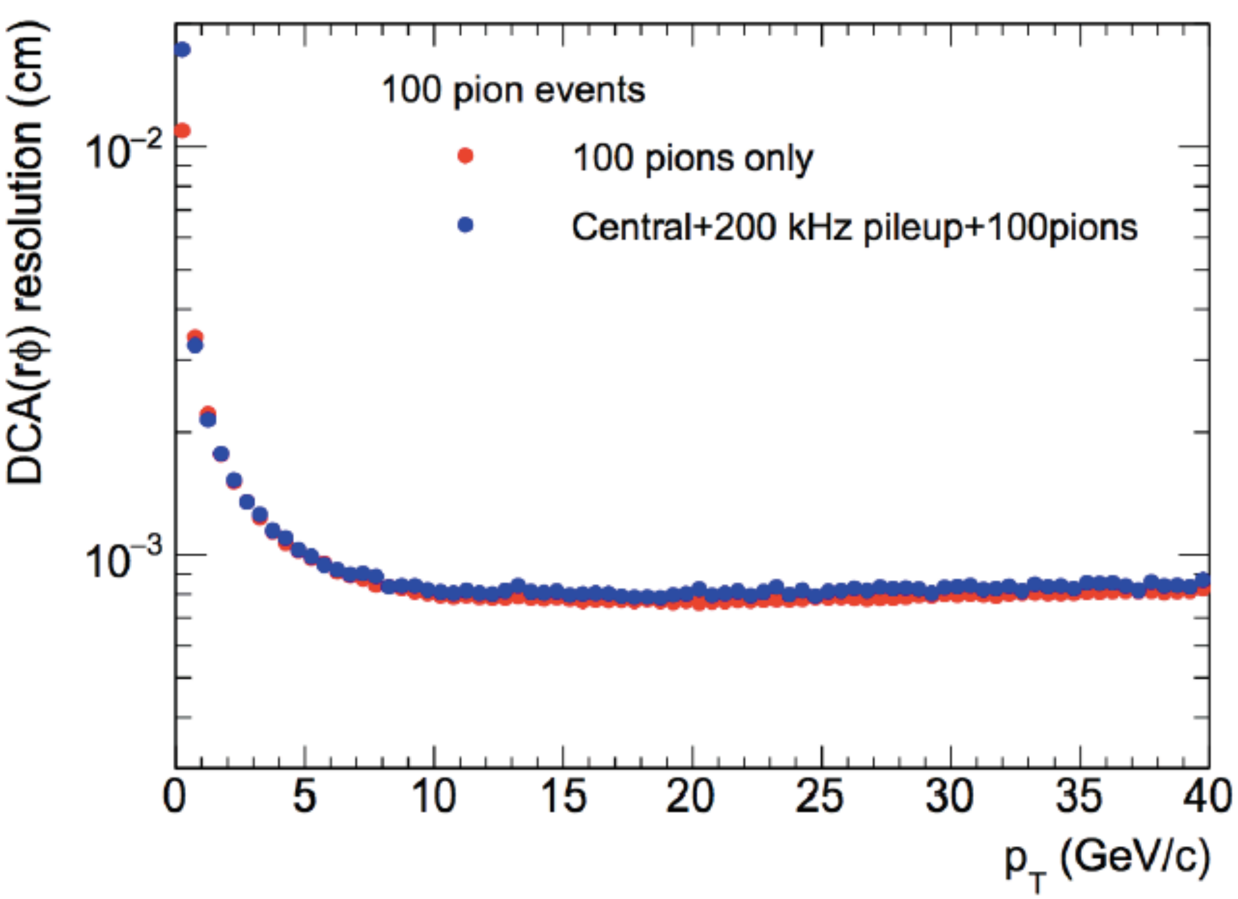
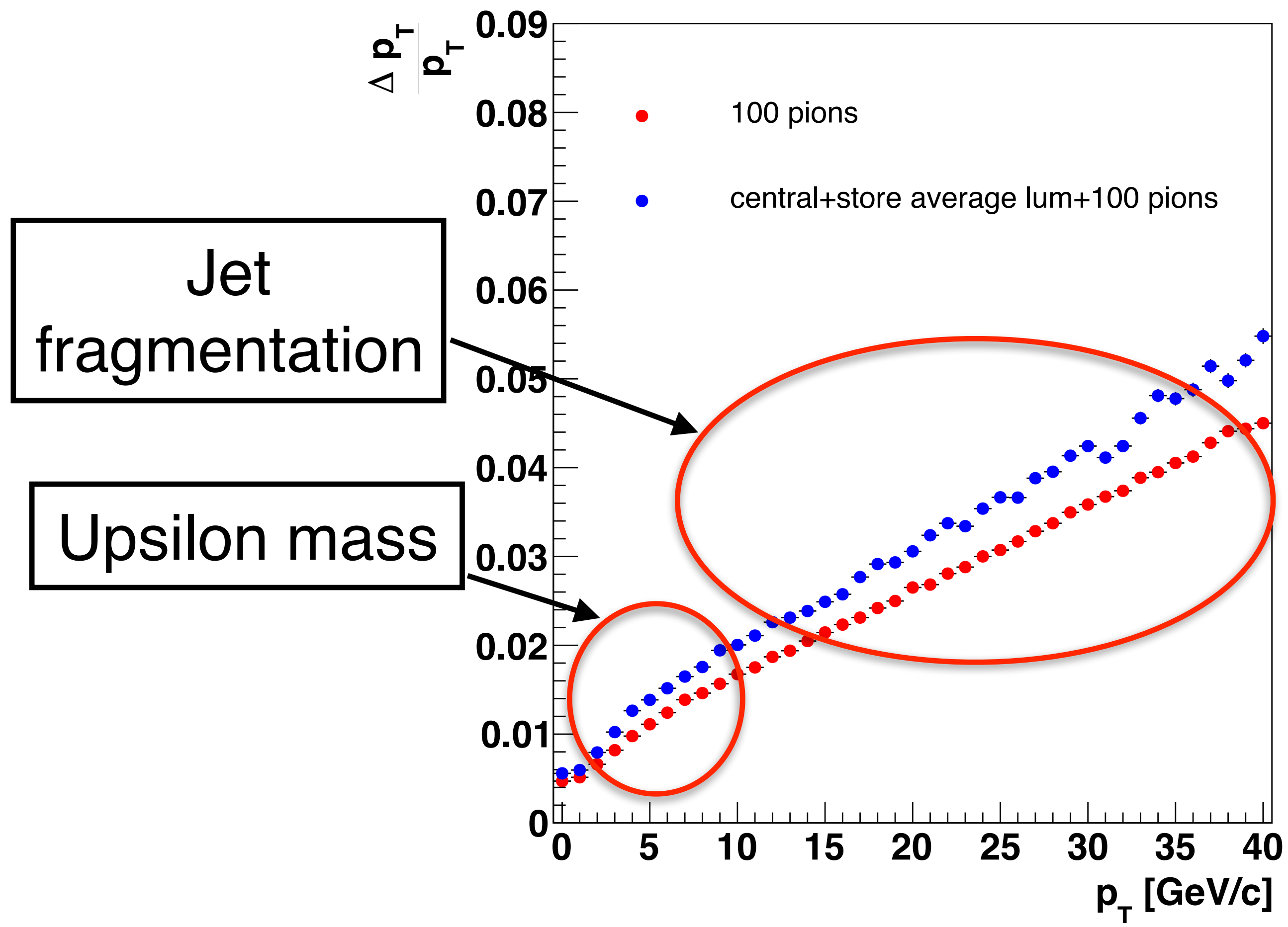
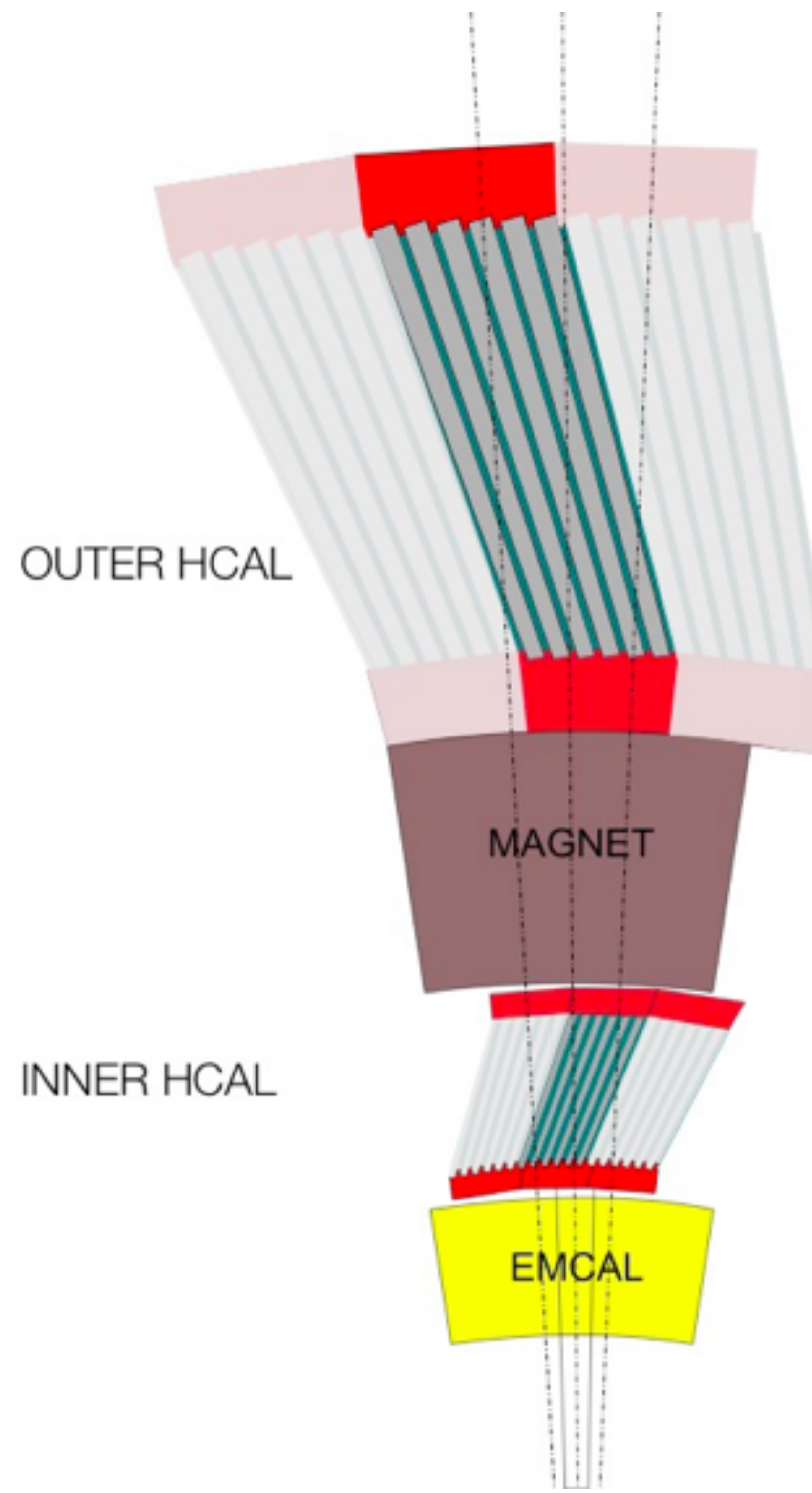






Calorimeters

EMCal
Tungsten-scintillating fiber sampling calorimeter
18 X_0, 1 λ
$\Delta\eta \times \Delta\phi = 0.025 \times 0.025$
Read out by silicon photomultipliers
2D projective geometry
Small Moliere Radius, short radiation length
Energy resolution $\leq 16\%/\sqrt{E}$ @ 5%



HCal
Sampling calorimeter
Magnet steel plates / scintillator tiles
3.8 λ
$\Delta\eta \times \Delta\phi = 0.1 \times 0.1$
Read out by silicon photomultipliers
Doubles as the flux return for the solenoid

Jet Physics Motivation

Broad goal

- understand coupling of the medium, origin of the coupling, and mechanism of rapid equilibration

sPHENIX will provide strong complementarity with the jet program at LHC:

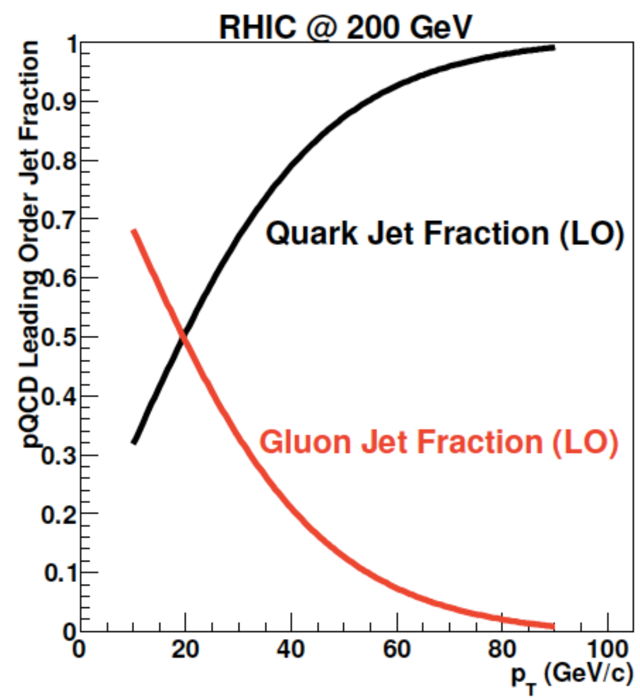
Smaller underlying event activity

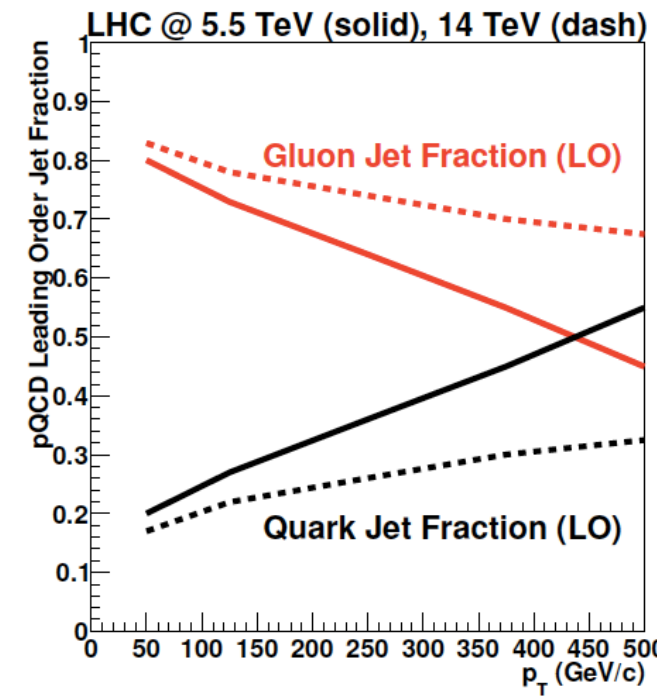
- Jets can be reconstructed to lower p_T
  - Probes longer distance scales
  - Smaller virtuality

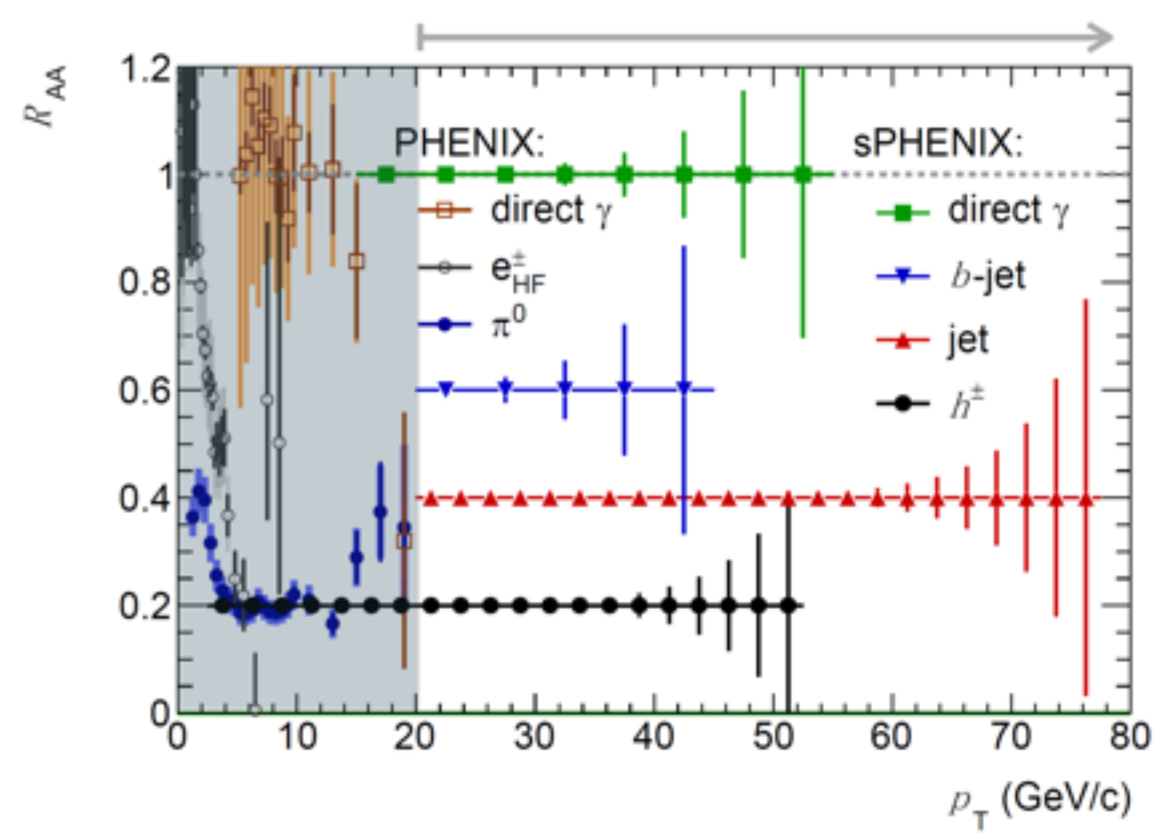
Jets evolve in a QGP that is closer to T_C at RHIC

- More sensitivity to 1-2 T_C

Different admixture of quark and gluon jets at RHIC







Jet Measurements

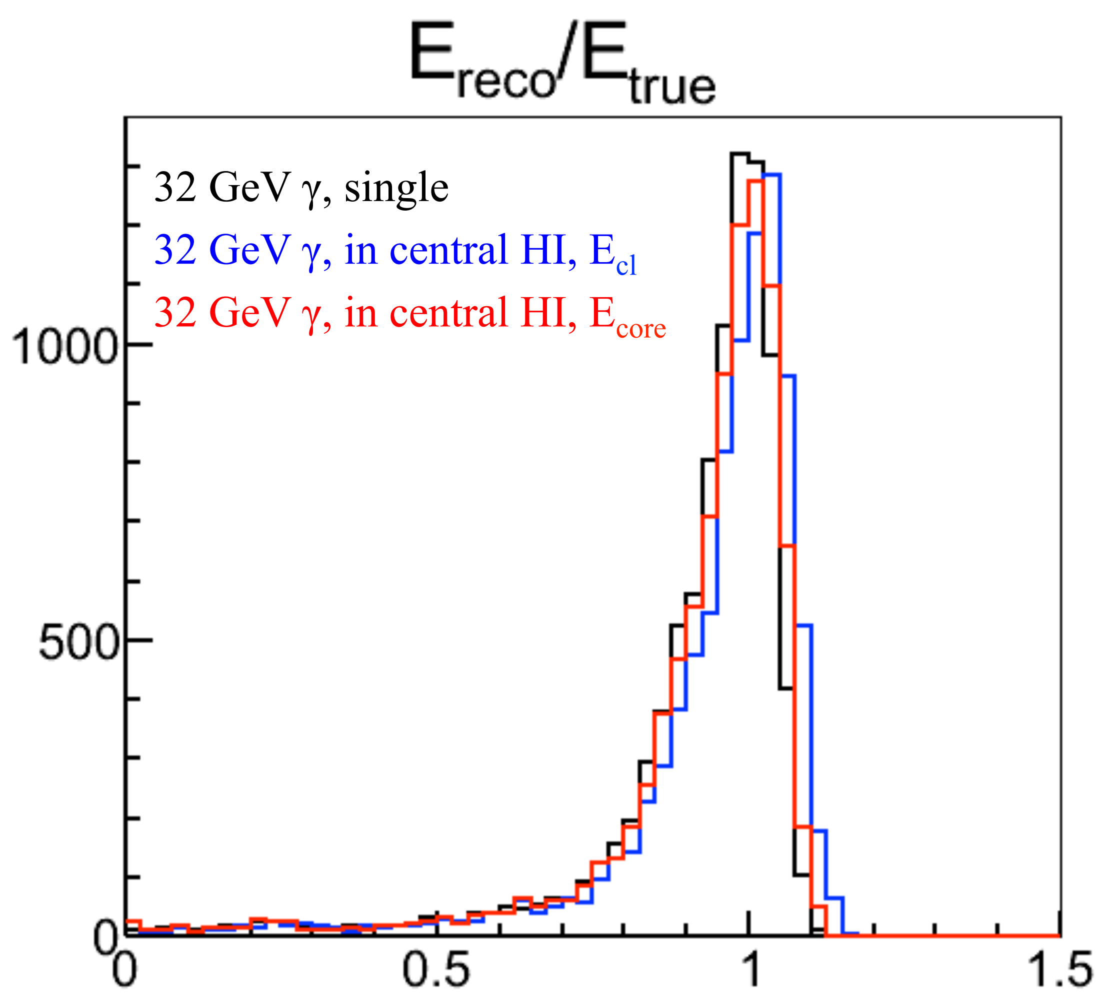
Di-jet asymmetry
- Sensitive to jet quenching in QGP

Photon-jet correlations
- How much energy is lost from the jet cone?
- Photon provides good access to parent parton of associated jet

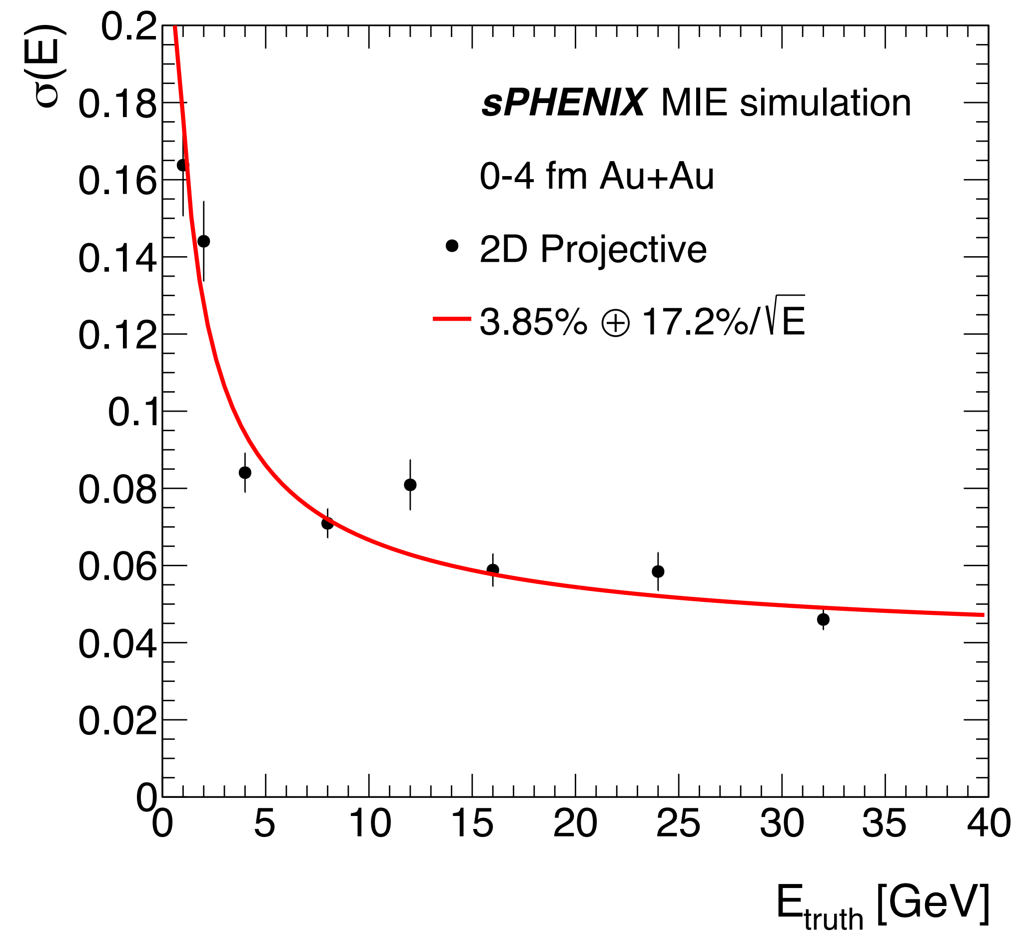
Jet fragmentation functions
- How is the parton shower modified in the medium?

Photon Reconstruction Performance

Full GEANT 4 simulation of photons in 2D projective EMCal



E_{reco} vs Et_{rue} for single photons vs photons embedded in b= 0-4 fm Au+Au events



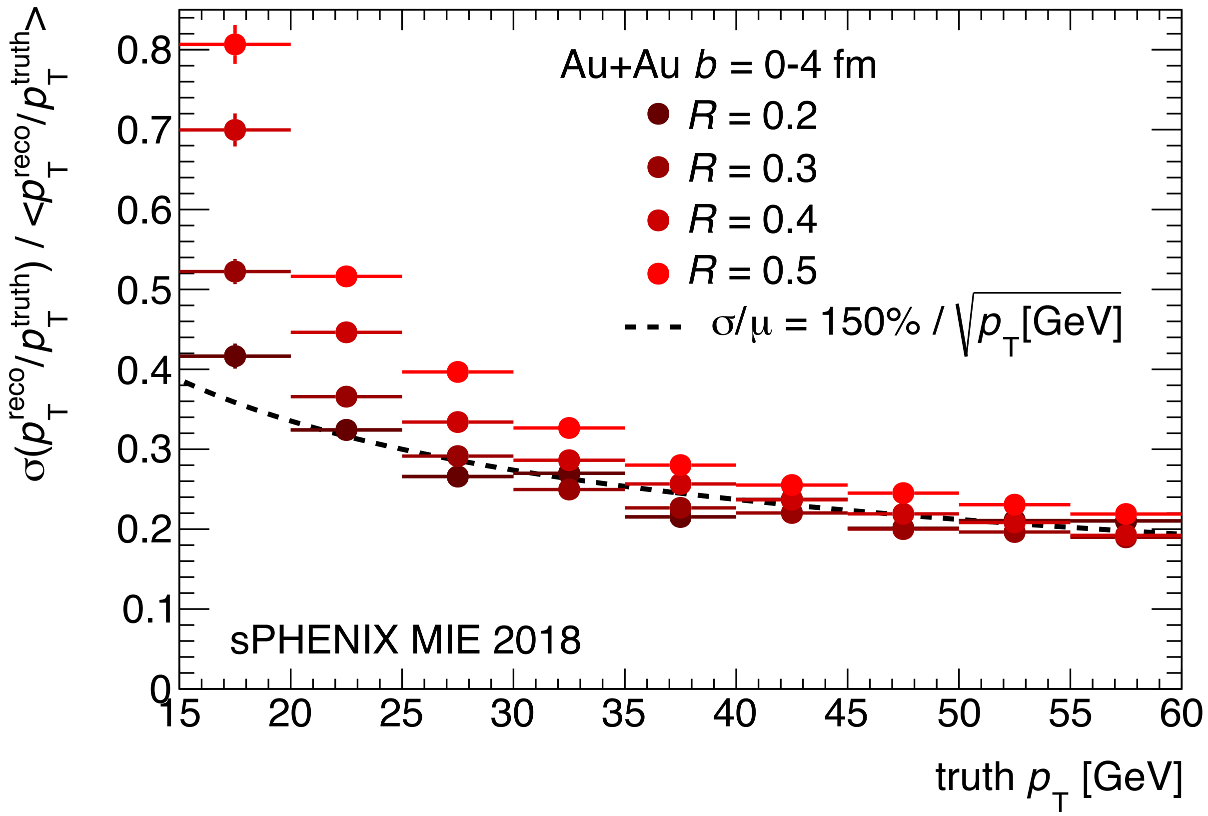
Energy resolution for photons in Hijing events

- Constrained by beam test measurements

Jet Reconstruction Performance

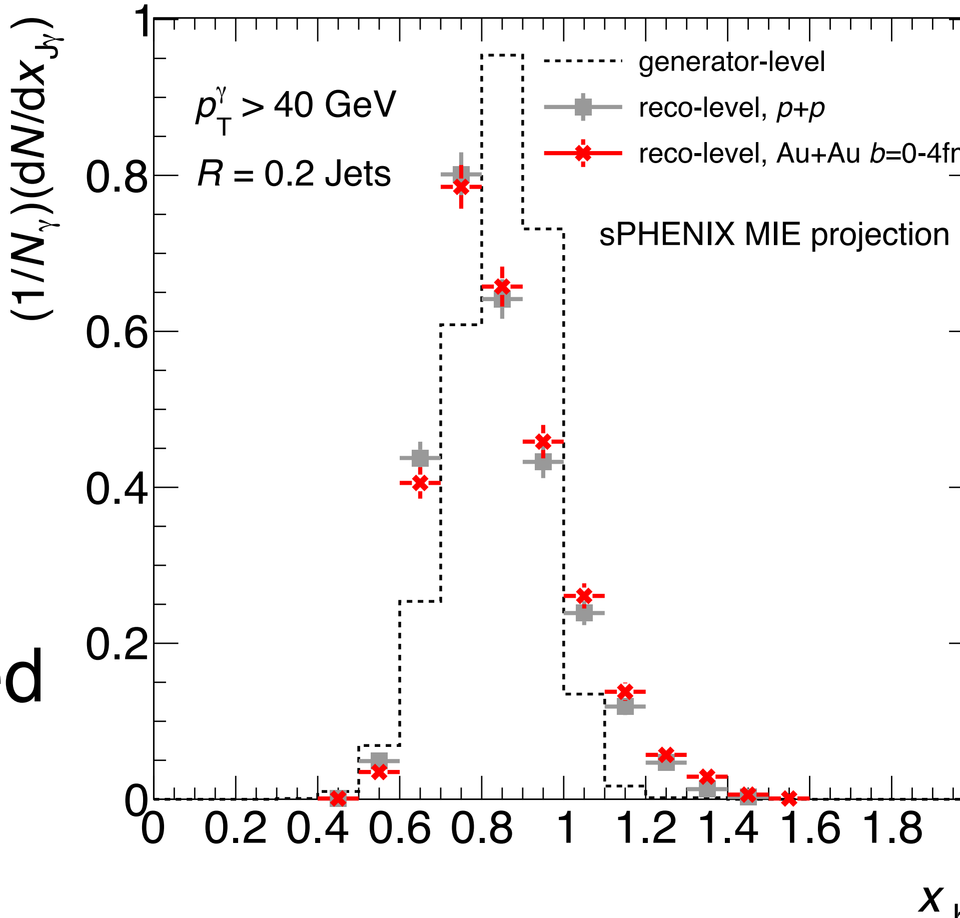
Full GEANT 4 simulation of jets embedded in central Hijing events

- Test of underlying event estimations and background subtraction



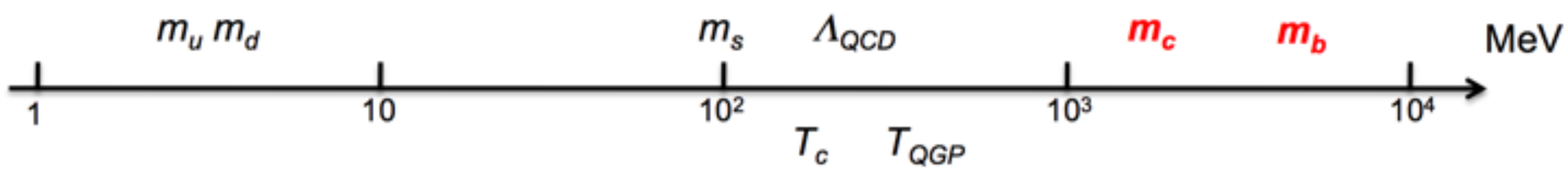
Jet p_T resolution in b= 0-4 fm Au+Au events for different cone sizes

- Anti-kT algorithm with FastJet package



Truth level and reconstructed photon-jet p_T ratio

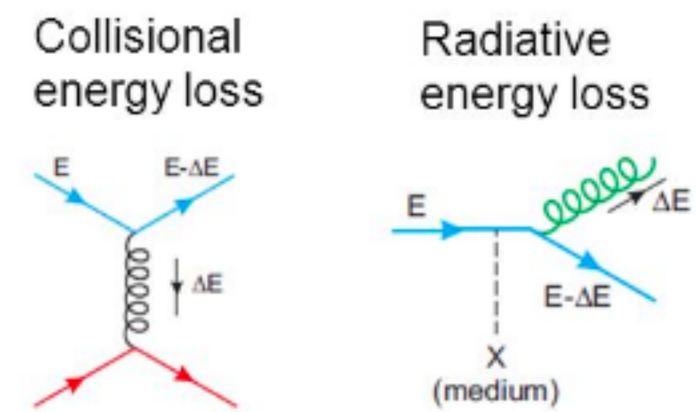
Heavy Flavor Physics Motivation



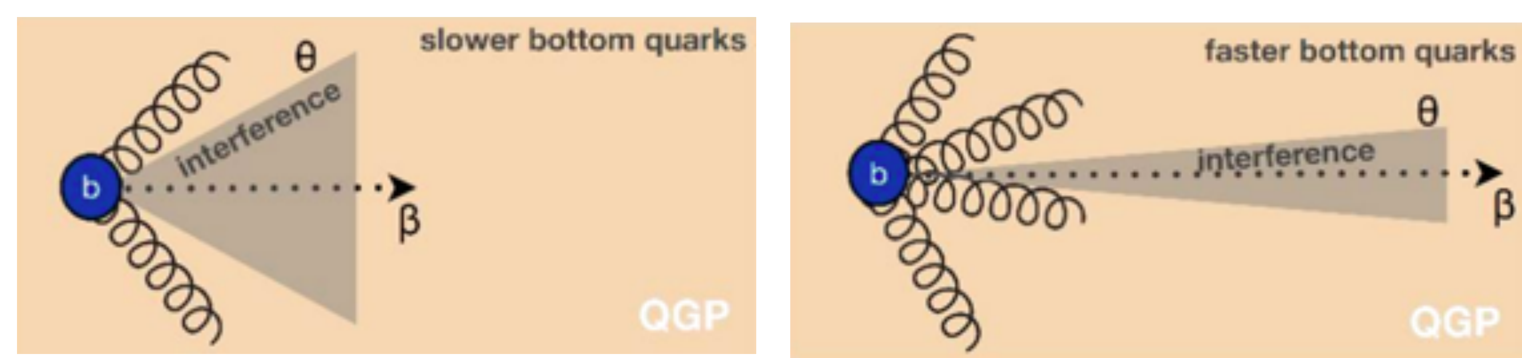
$m_{c,b} >> \Lambda_{QCD}$ *amenable to perturbative QCD*

$m_{c,b} >> T_{QGP}$ *predominately created from initial hard scatterings*

Heavy quarks are sensitive to different energy loss mechanisms



Also sensitive to momentum

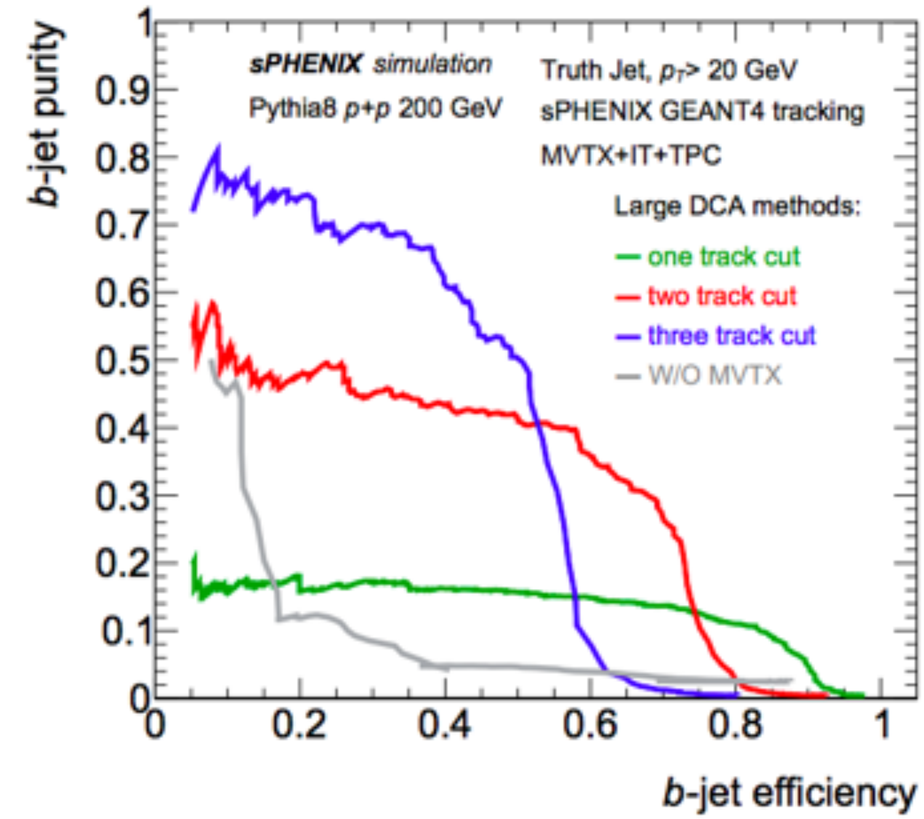


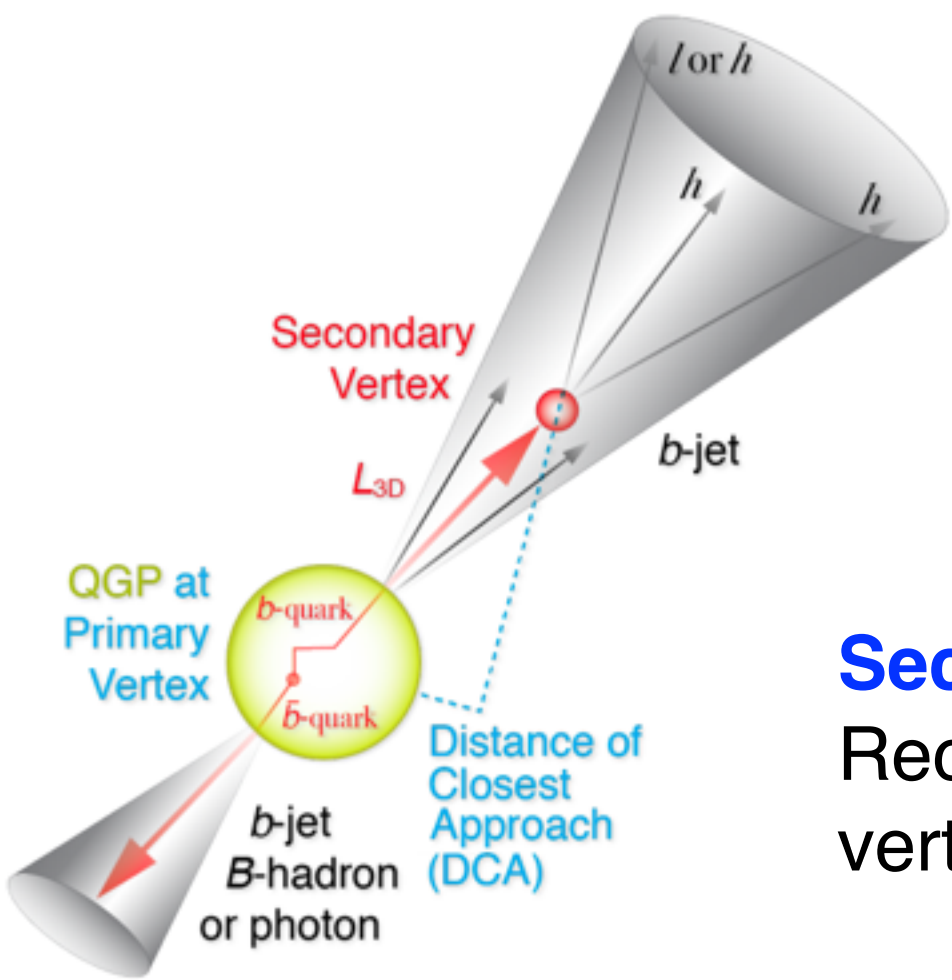
We want to measure bottom from low to high momentum
- Precise measurement of track origin
- High luminosity

Tagging *b* - Jets

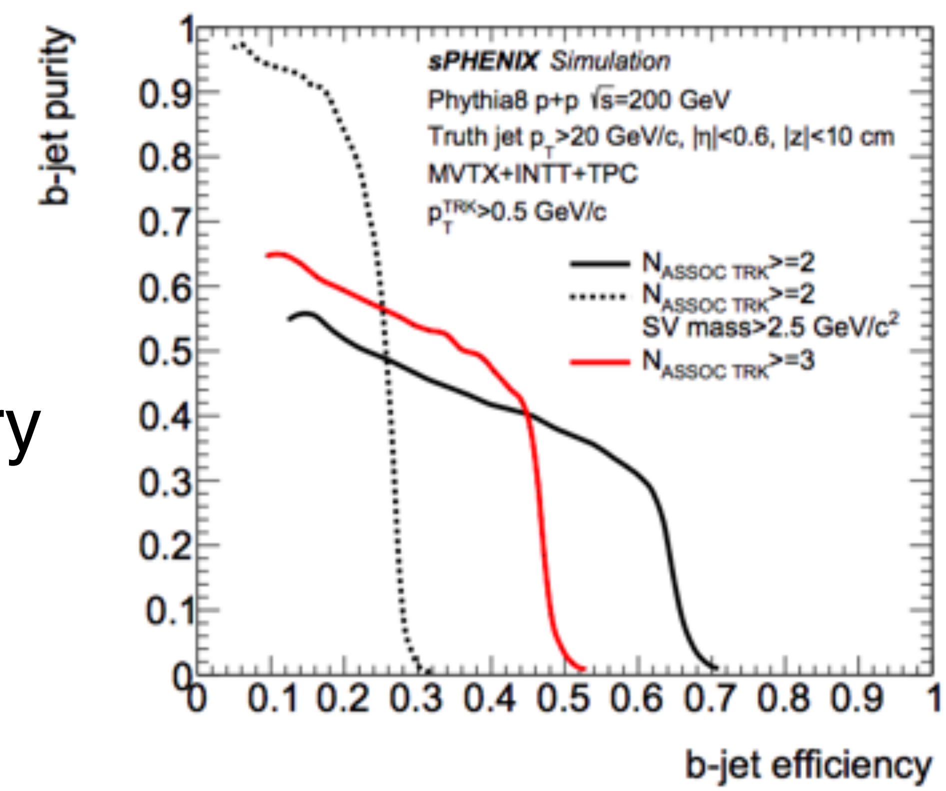
Two methods provide complementarity and cross checks

Large DCA:
Count tracks with DCA outside a cut relative to the event vertex



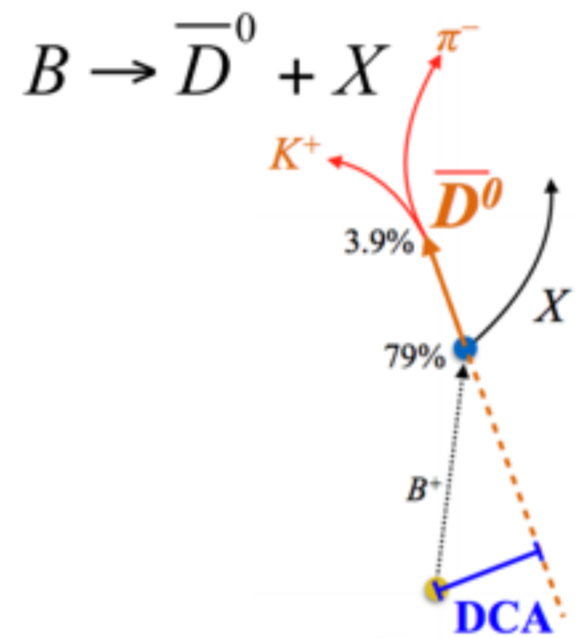


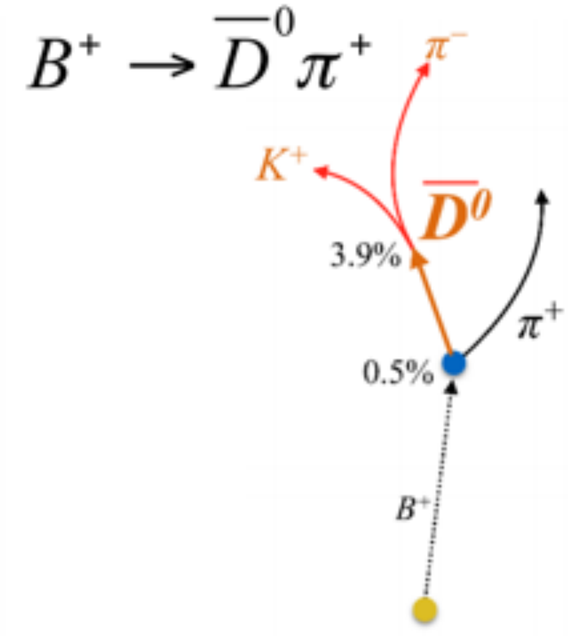
Secondary Vertex:
Reconstruct secondary vertex within jet



Heavy Flavor Measurements

Measure B hadrons through displaced vertex secondaries, or through complete reconstruction.



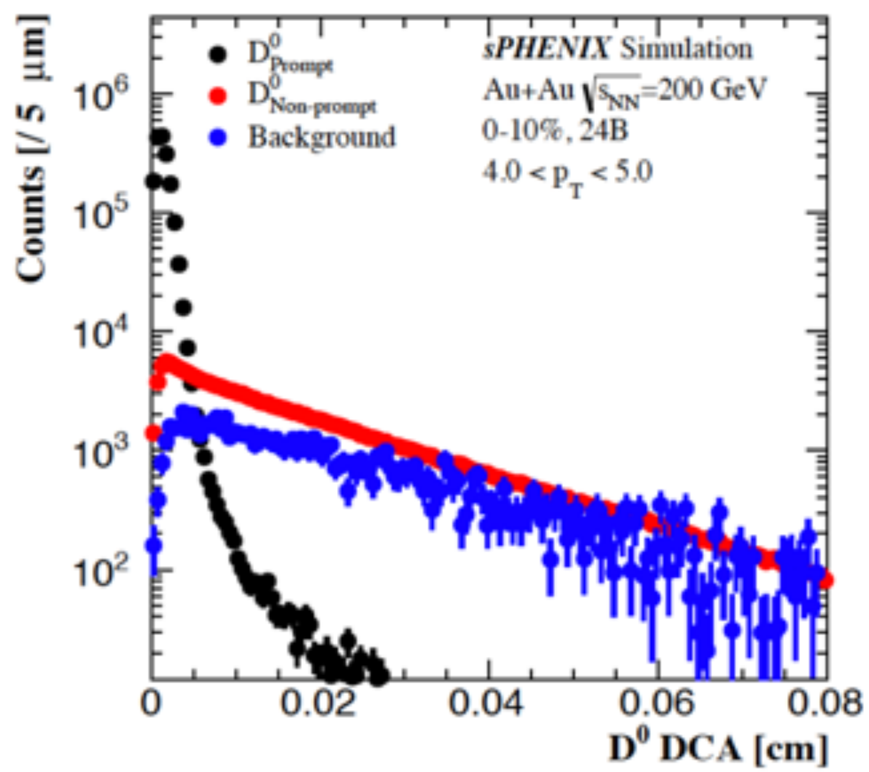


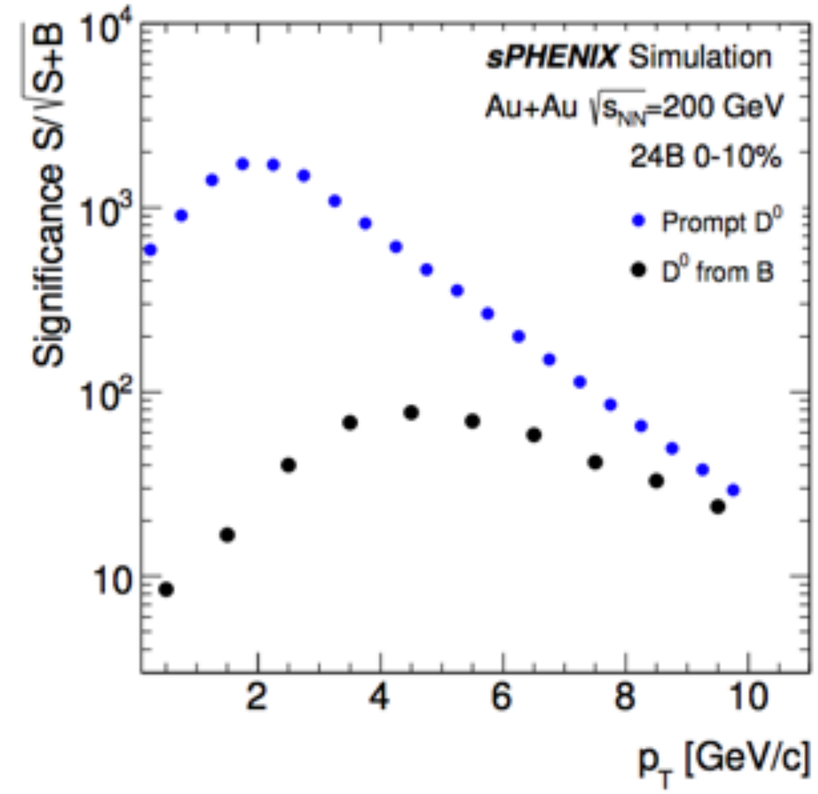
Hadron	Abundance	cτ (μm)
D^0	61%	123
D^+	24%	312
D_s	8%	150
Λ_c	6%	60
B^+	40%	491
B^0	40%	455
B_s	10%	453
Λ_b	10%	435

Hadron	Decay Channel	B.R.
b-hadron admixture	D^0 + anything	(59.5 ± 2.9) %
	J/ψ + anything	(1.16 ± 0.10) %
	e^- + anything	(10.86 ± 0.35) %
B^+	$\overline{D}^0 + \pi^+$	(0.480 ± 0.015) %
	$J/\psi + K^+$	(0.103 ± 0.003) %

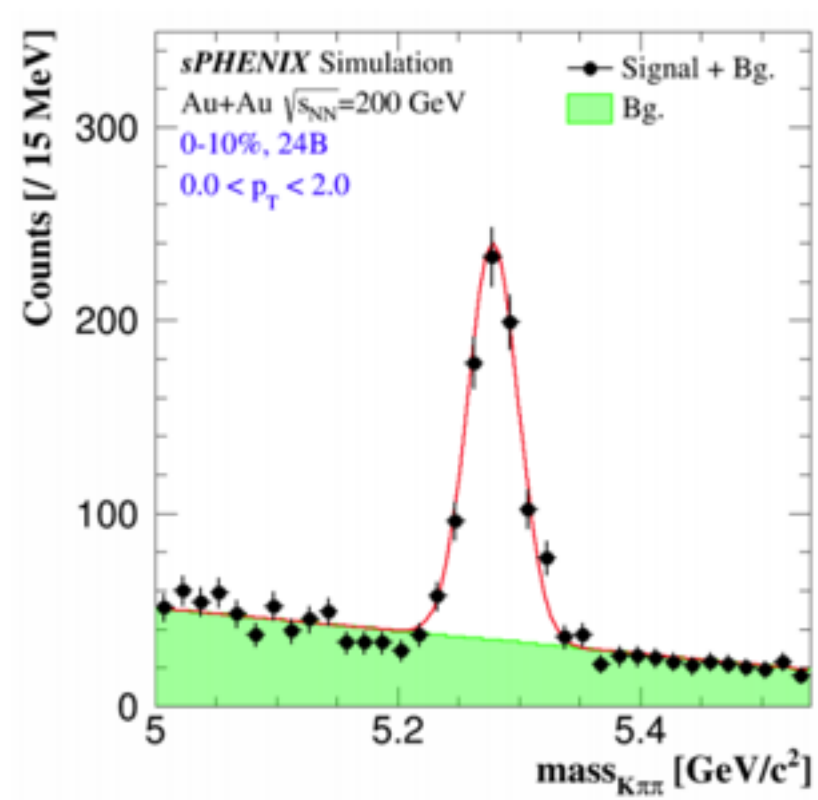
Heavy flavor Measurements

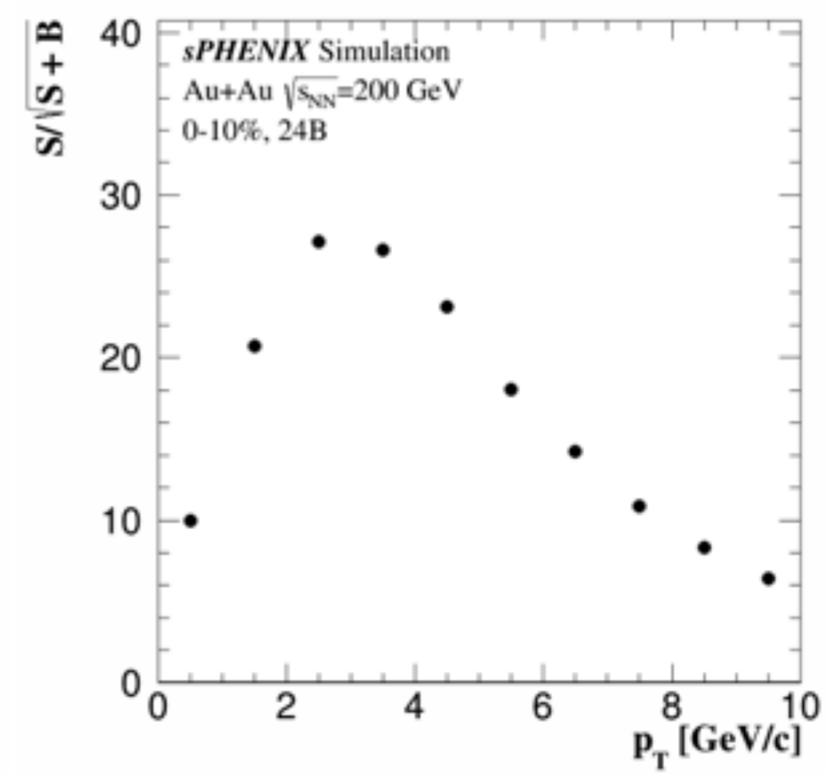
Non-prompt D^0





B^+ reconstruction



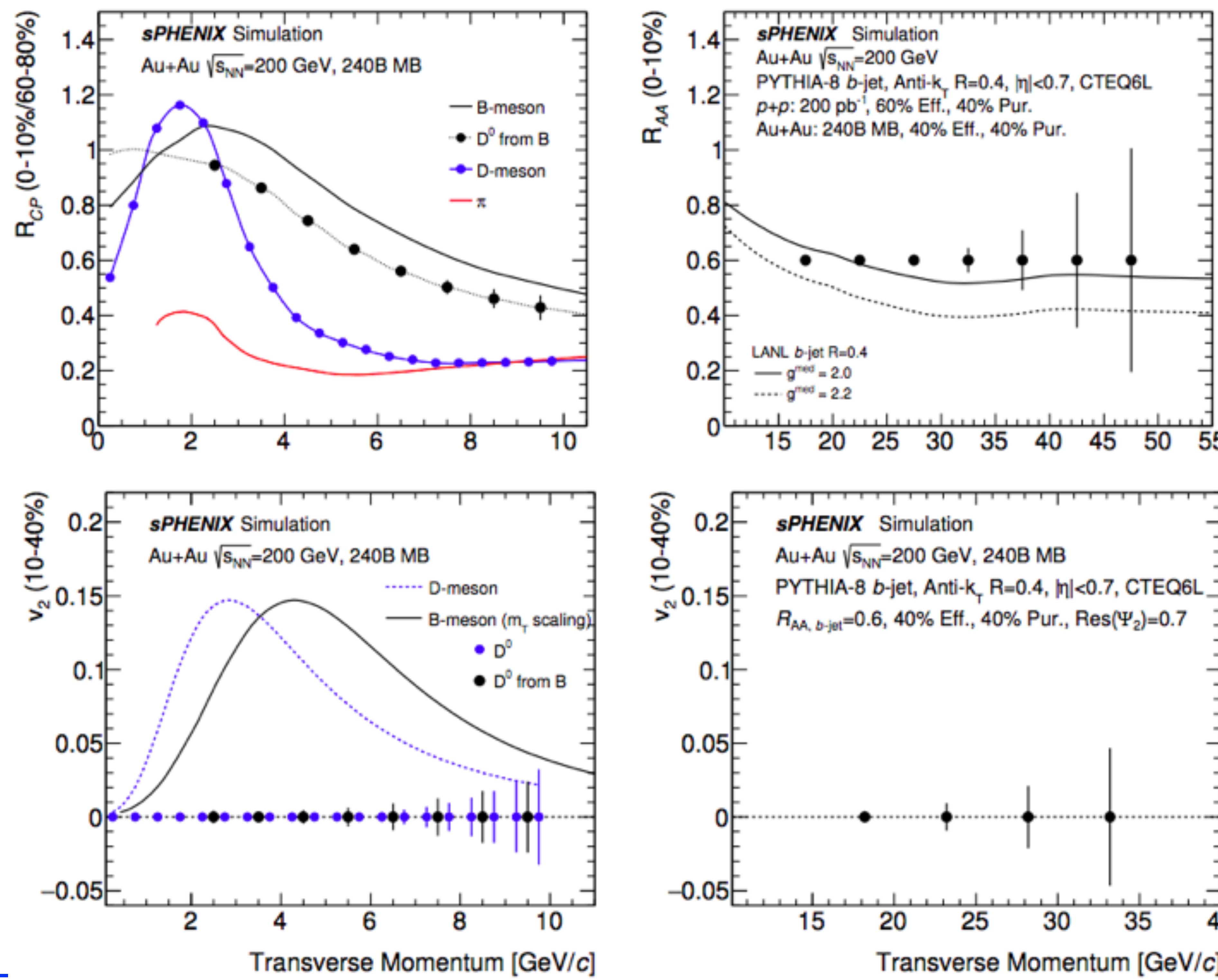


Performance for heavy flavor

Full GEANT 4 simulation of HF decays embedded in central Hijing events

(**left**) Precision of R_{CP} for non-prompt and prompt D^0 **(right)** Precision of R_{AA} for b-jets

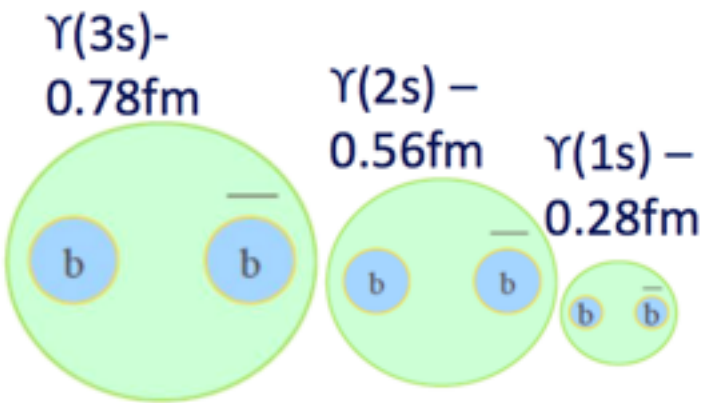
(**left**) Precision of v_2 for non-prompt and prompt D^0 (**right**) for reconstructed b-jets



Upsilon Physics Motivation

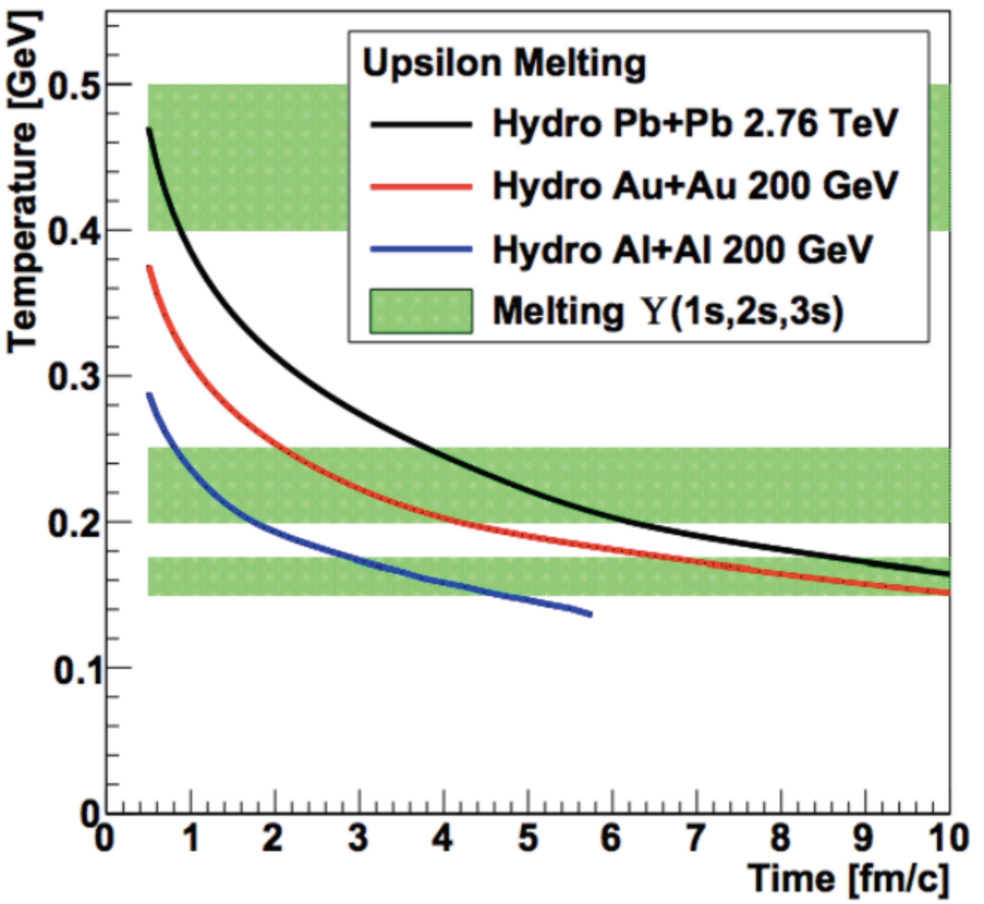
Three states with very different binding energy and radii

- All with experimentally observable dilepton decay yields
- Different sensitivity to QGP conditions

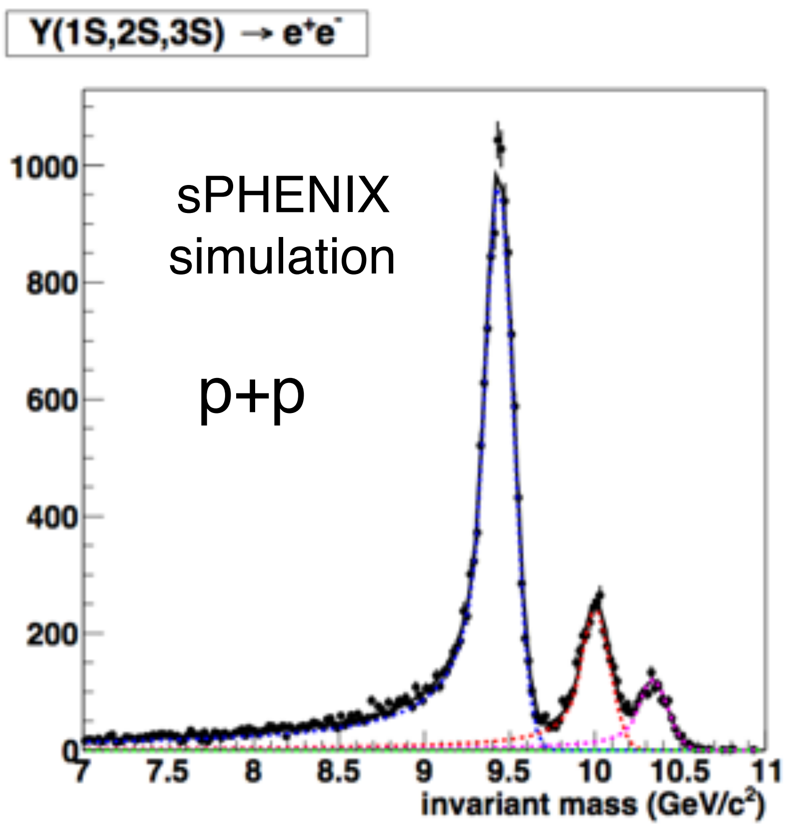


Complementary to LHC:

- Samples QGP in different temperature region
- Underlying b+b yield is very different
  - ~ 0.05 / Au+Au event at RHIC
  - ~ 5 / Pb+Pb event at LHC
- Minimal coalescence at hadronization at RHIC

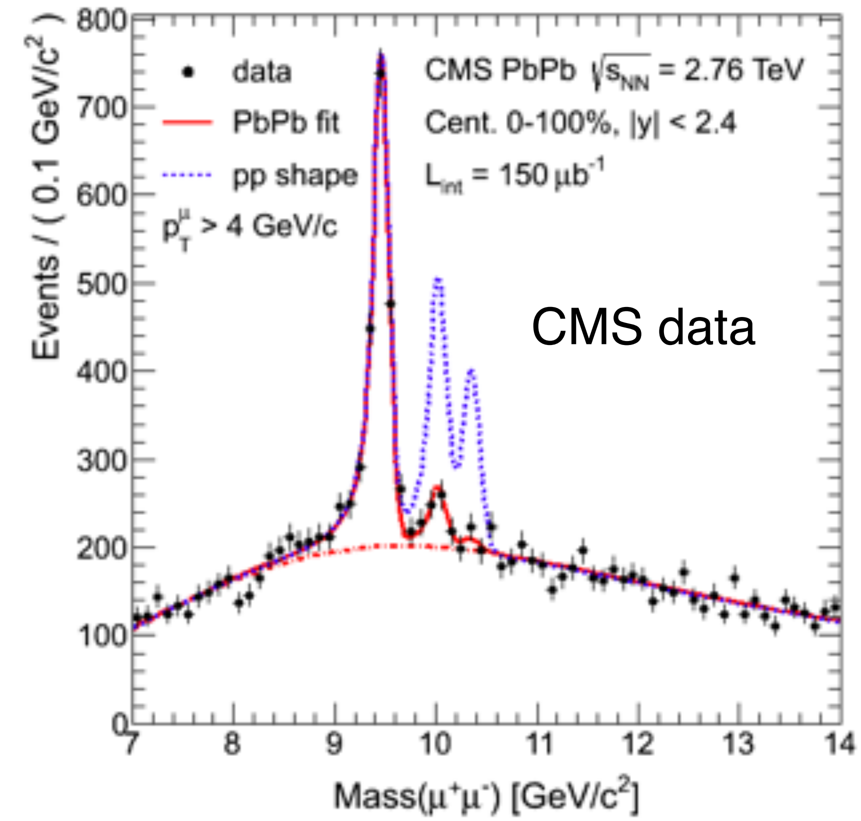


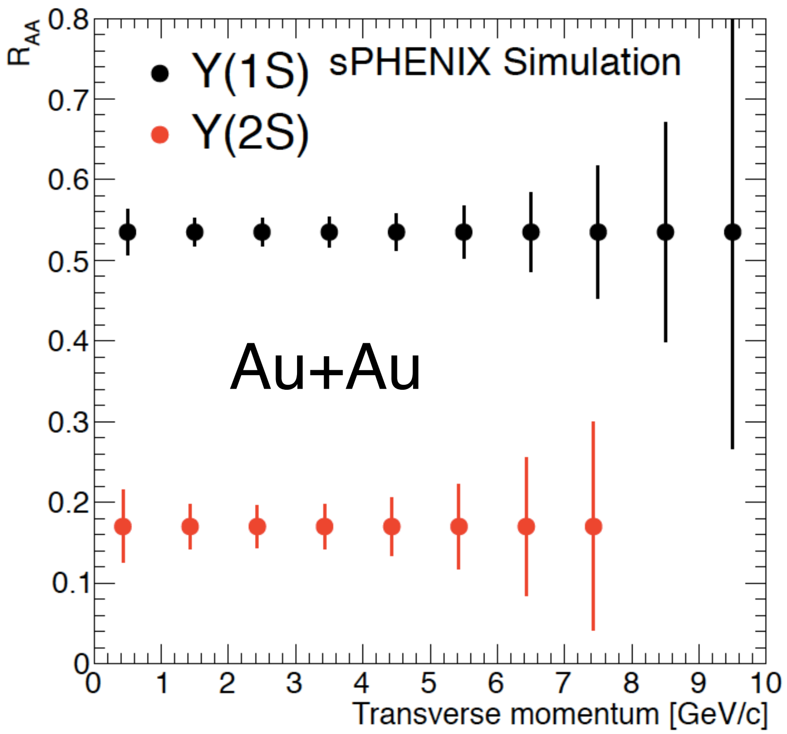
Upsilon Measurements



Simulated mass spectrum in p+p collisions (left).

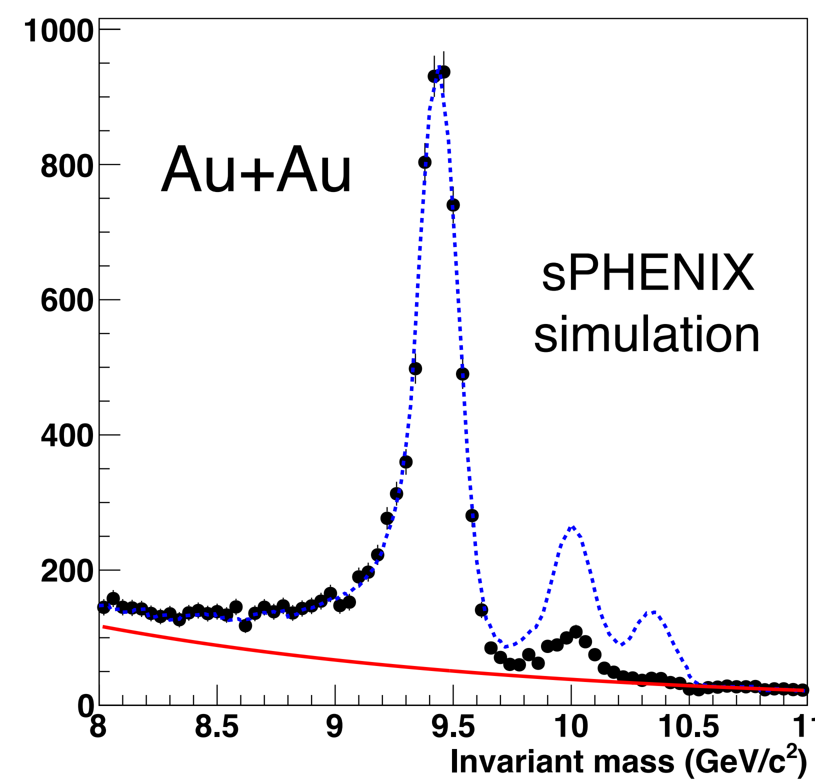
CMS data for p+p, Pb+Pb (right).





Simulated mass spectrum in 0-10% central Au+Au collisions.

- Suppression taken from Strickland & Bazow.



Multi-year sPHENIX run plan

Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
Year-1	Au+Au	200	16.0	7 nb^{-1}	8.7 nb^{-1}	34 nb^{-1}
Year-2	p+p	200	11.5	—	48 pb^{-1}	267 pb^{-1}
Year-2	p+Au	200	11.5	—	0.33 pb^{-1}	1.46 pb^{-1}
Year-3	Au+Au	200	23.5	14 nb^{-1}	26 nb^{-1}	88 nb^{-1}
Year-4	p+p	200	23.5	—	149 pb^{-1}	783 pb^{-1}
Year-5	Au+Au	200	23.5	14 nb^{-1}	48 nb^{-1}	92 nb^{-1}

- Guidance from ALD to think in terms of a multi-year run plan
- Consistent with language in DOE CD-0 "mission need" document
- Based on BNL C-AD guidance on projected luminosity
- Incorporates commissioning time in first year
- Structured so that first three years delivers at least minimum science program

Minimum bias Au+Au at 15 kHz for |z| < 10 cm:

47 billion (Year-1) + **96 billion** (Year-2) + **96 billion** (Year-3) = Total **239 billion events**

For topics with Level-1 selective trigger (e.g. high p_T photons), one can sample within |z| < 10 cm a total of 550 billion events. One could sample events over a wider z-vertex for calorimeter only measurements, 1.5 trillion events.

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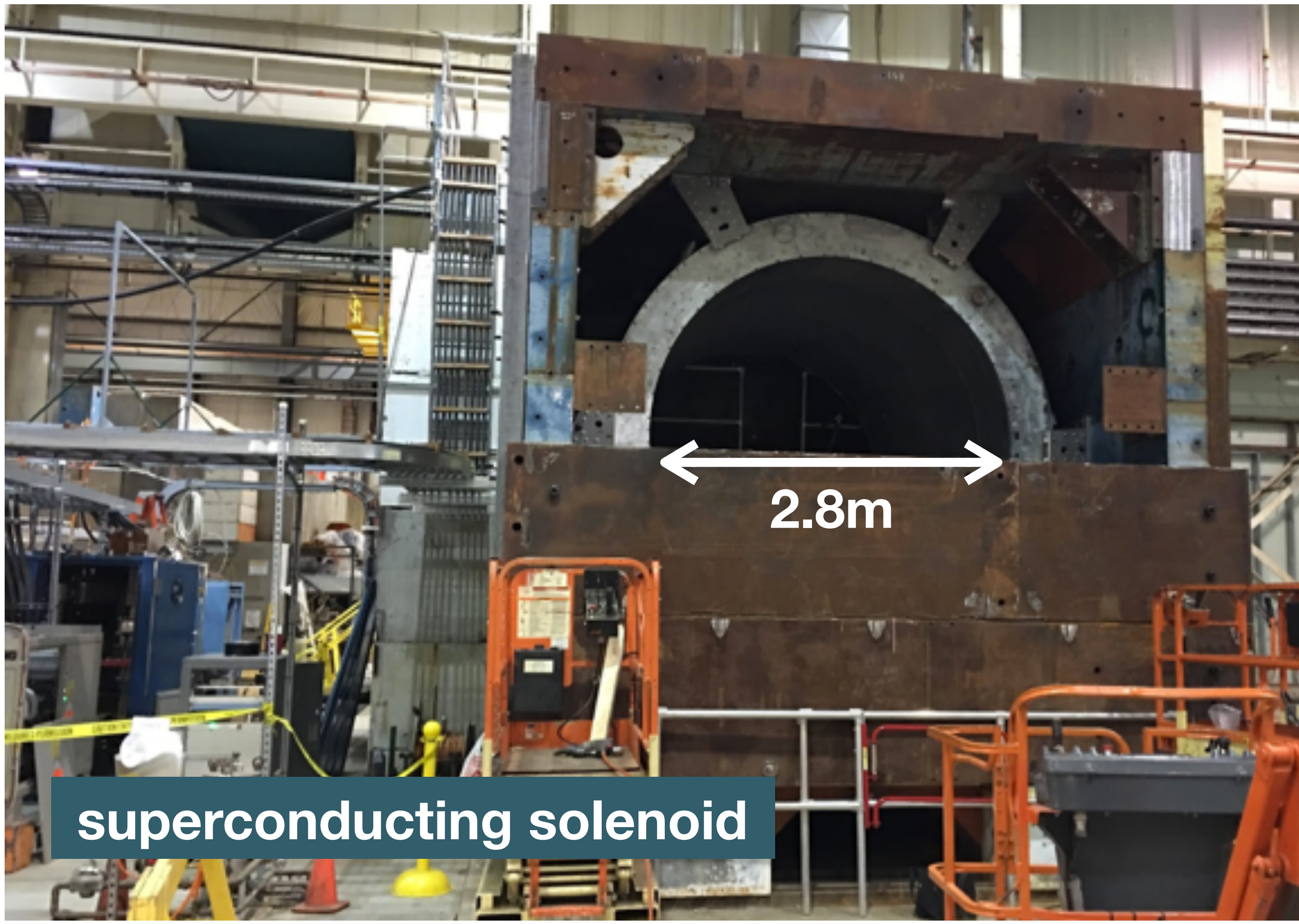
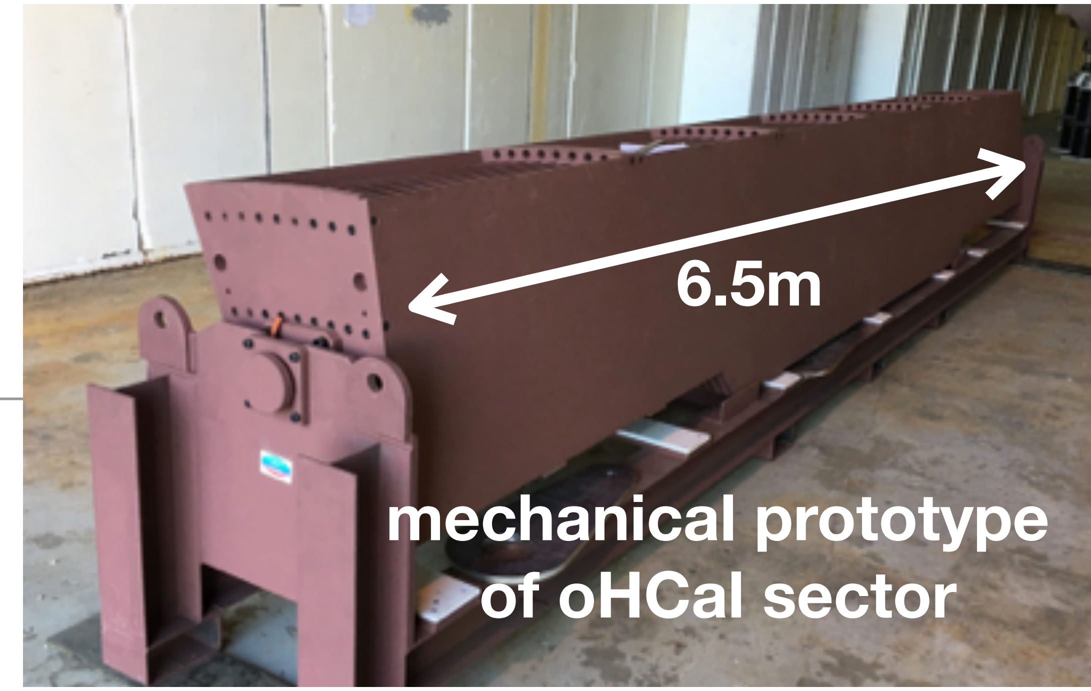
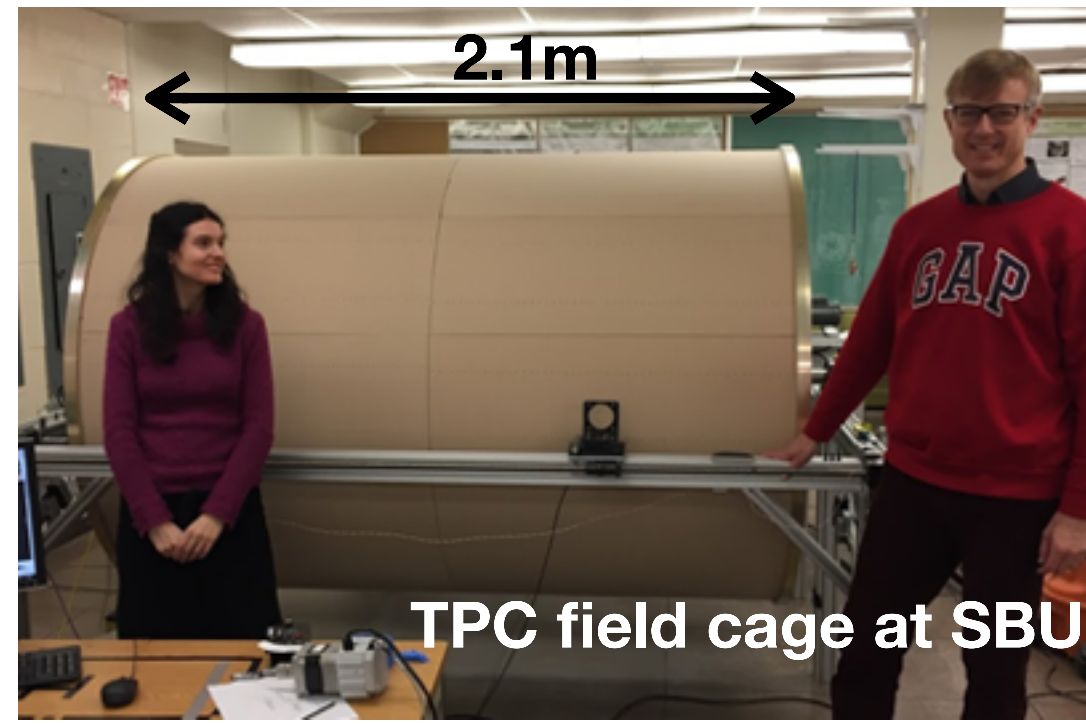
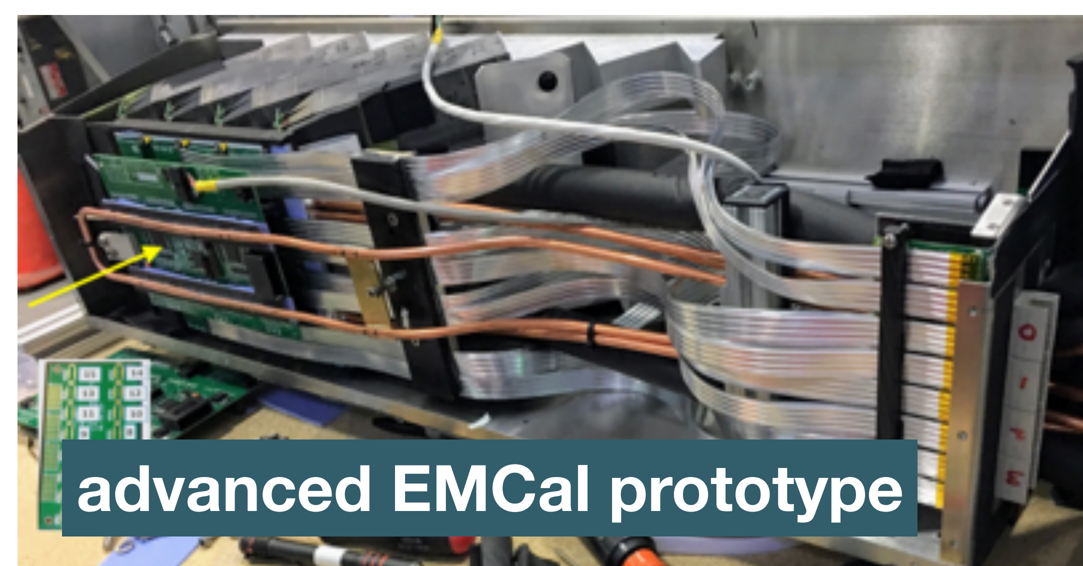
Marching toward reality





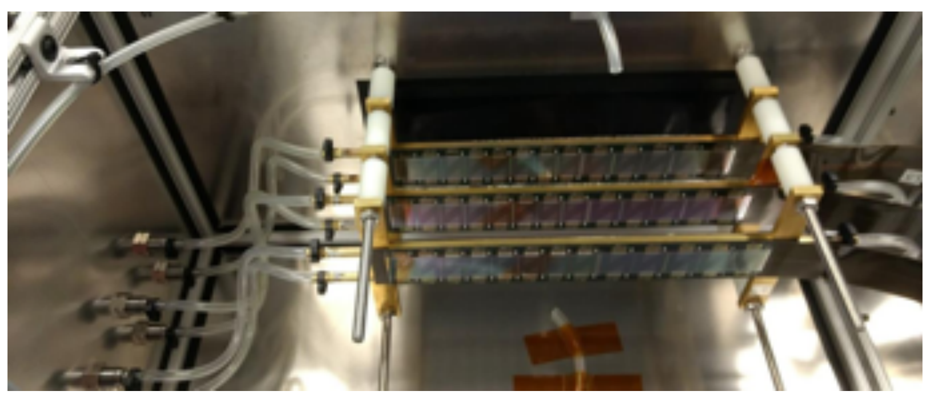




- Magnet successfully tested to full current
- Contract awarded for full order of oHCal steel
- Full chain tests of calorimeter stack, MVTX telescope, INTT telescope, readout electronics
- TPC prototype to see test beam next week

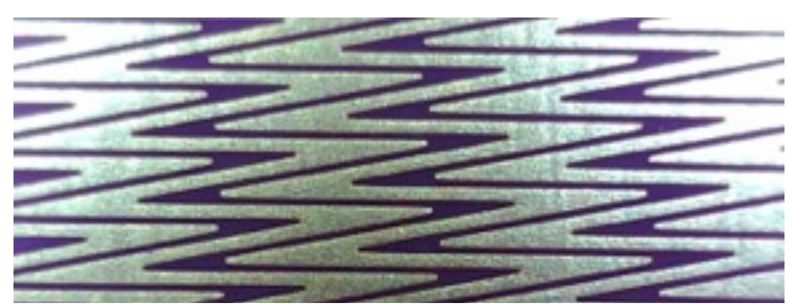
R&D well underway for all detectors

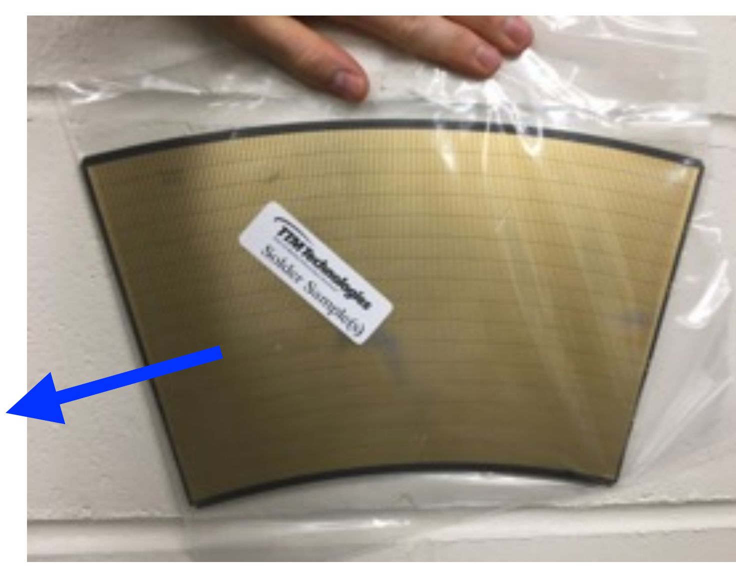
MVTX & INTT test beam at FNAL
- February, March 2018



INTT telescope

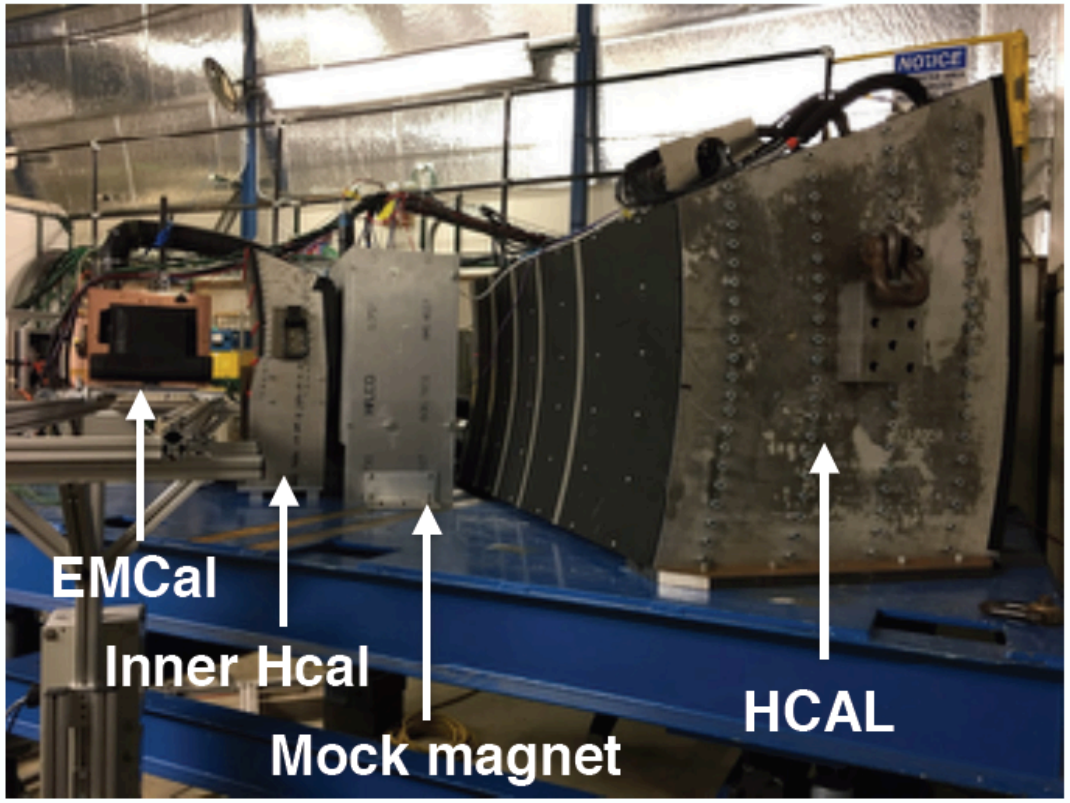
TPC chevron
pad plane





MVTX 4 sensor telescope
+ full readout chain

R&D well underway for all detectors

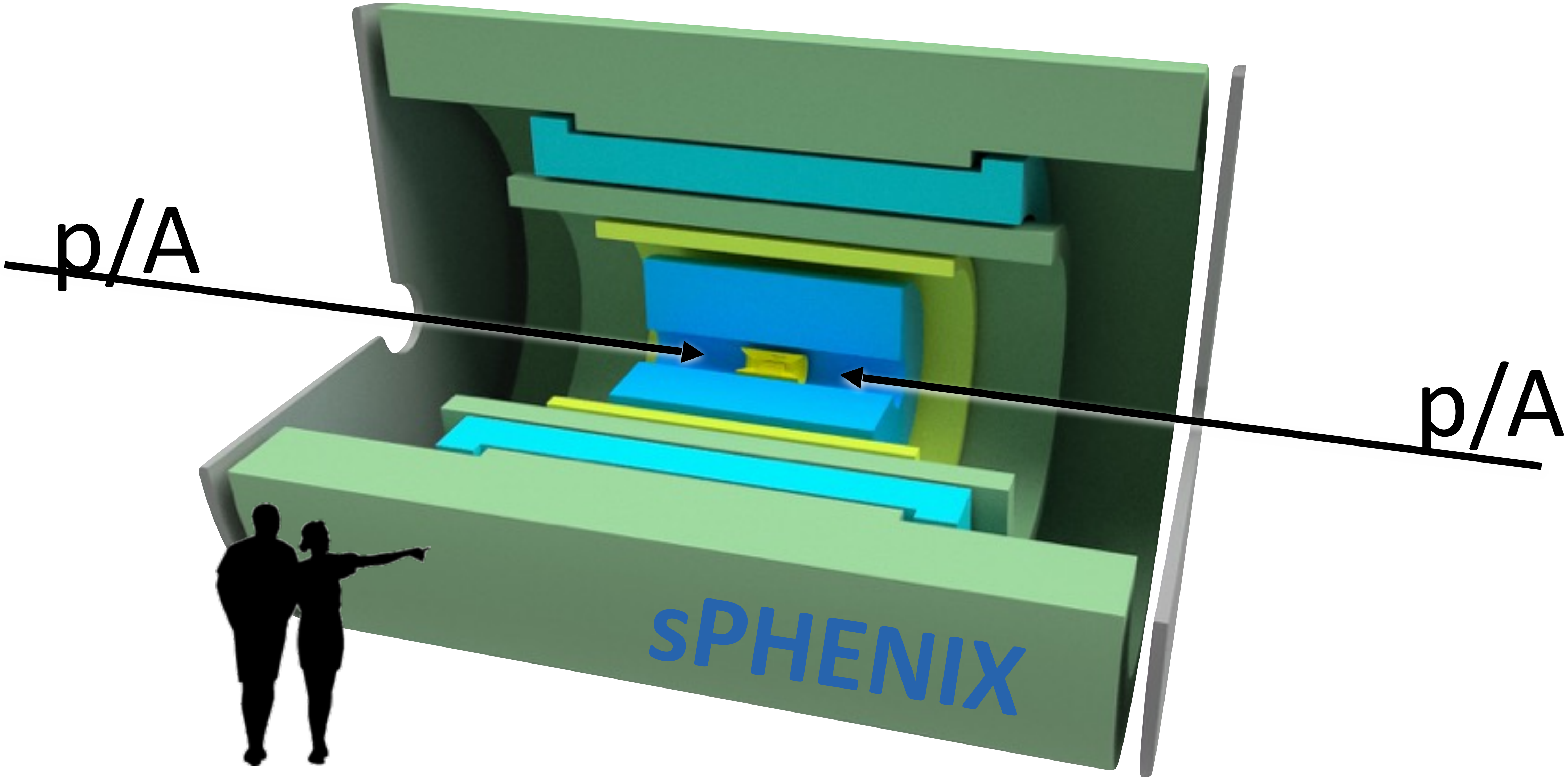


Set up for Calorimeters beam test at FNAL Feb-March 2018

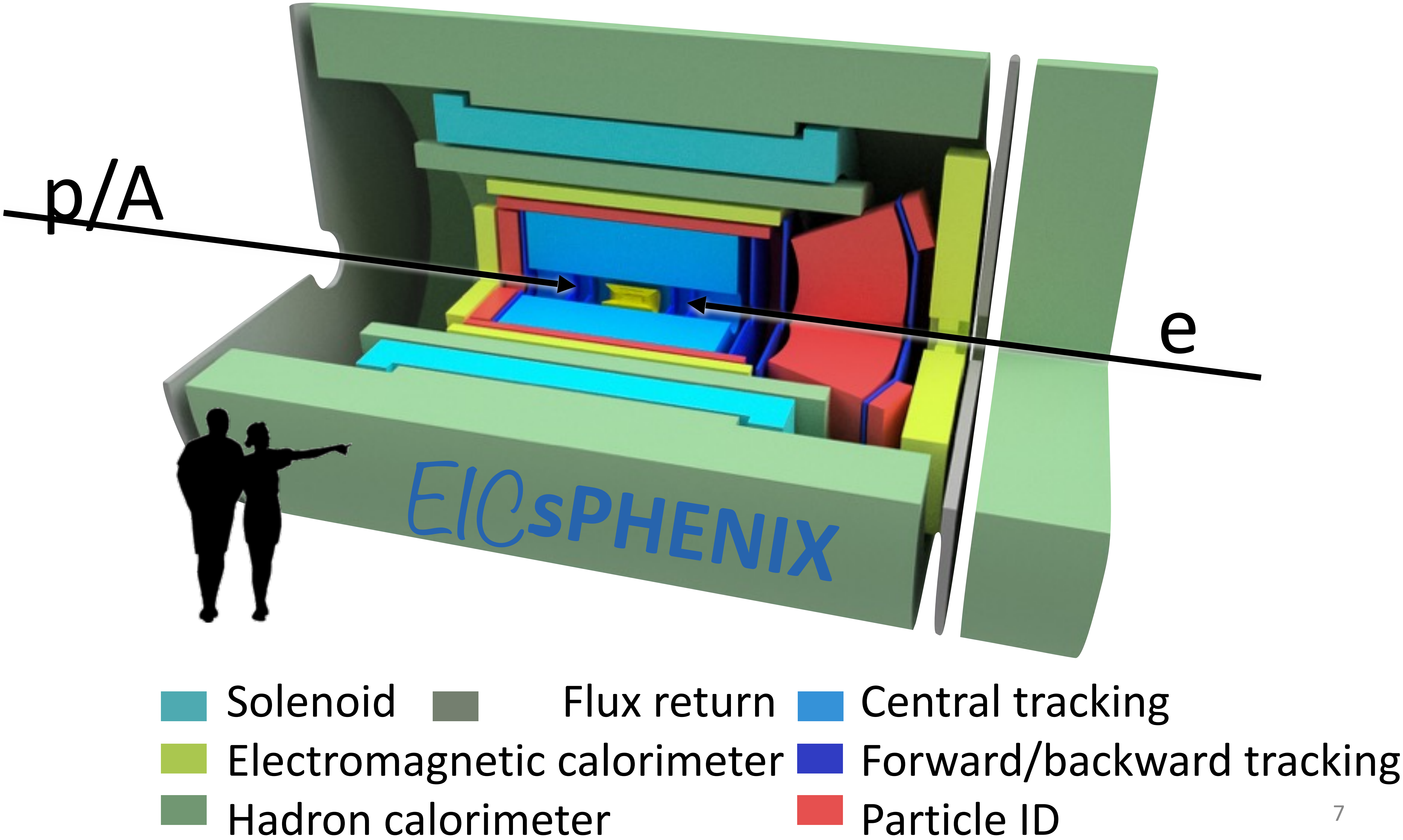
Block production begins this month for a pre-production EMCal sector

Setup to be used for HCal tile testing during production

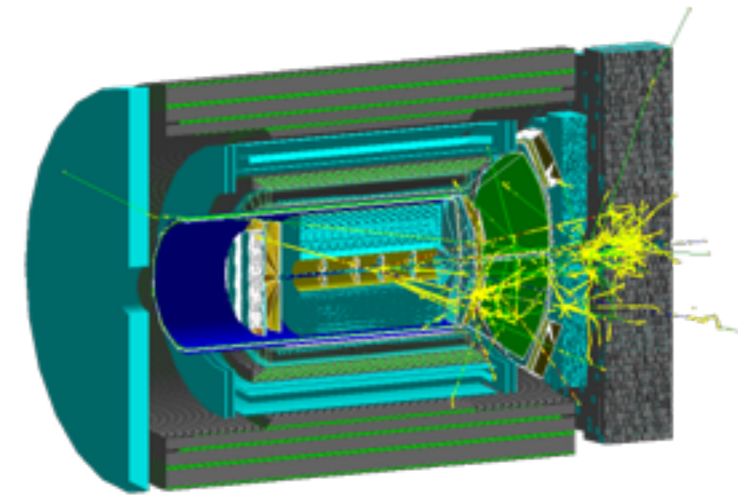
From Christine Aidala's PAC presentation on June 7



Solenoid Flux return Central tracking
Electromagnetic calorimeter
Hadron calorimeter


p/A
e
EICsPHENIX
Solenoid
Flux return
Central tracking
Electromagnetic calorimeter
Forward/backward tracking
Hadron calorimeter
Particle ID

Conclusions and outlook



- An EIC detector based on sPHENIX can address the full physics program of the facility, spanning inclusive, semi-inclusive, and exclusive measurements.
- Efforts have ramped up investigating realistic possible implementations—lots of technical progress since 2014 LOI.
- Delivery of LOI in September will mark a milestone within ongoing work toward an EIC detector based on sPHENIX.

Collaboration

Growing collaboration - number of institutions is now > 70

Collaboration meeting June 5-6 had > 50 participants

On May 23-25 we had a very positive DOE OPA CD1/3A review!

Collaboration

We welcome new collaborators! There are many opportunities to contribute to the physics program and to detector R&D and construction.